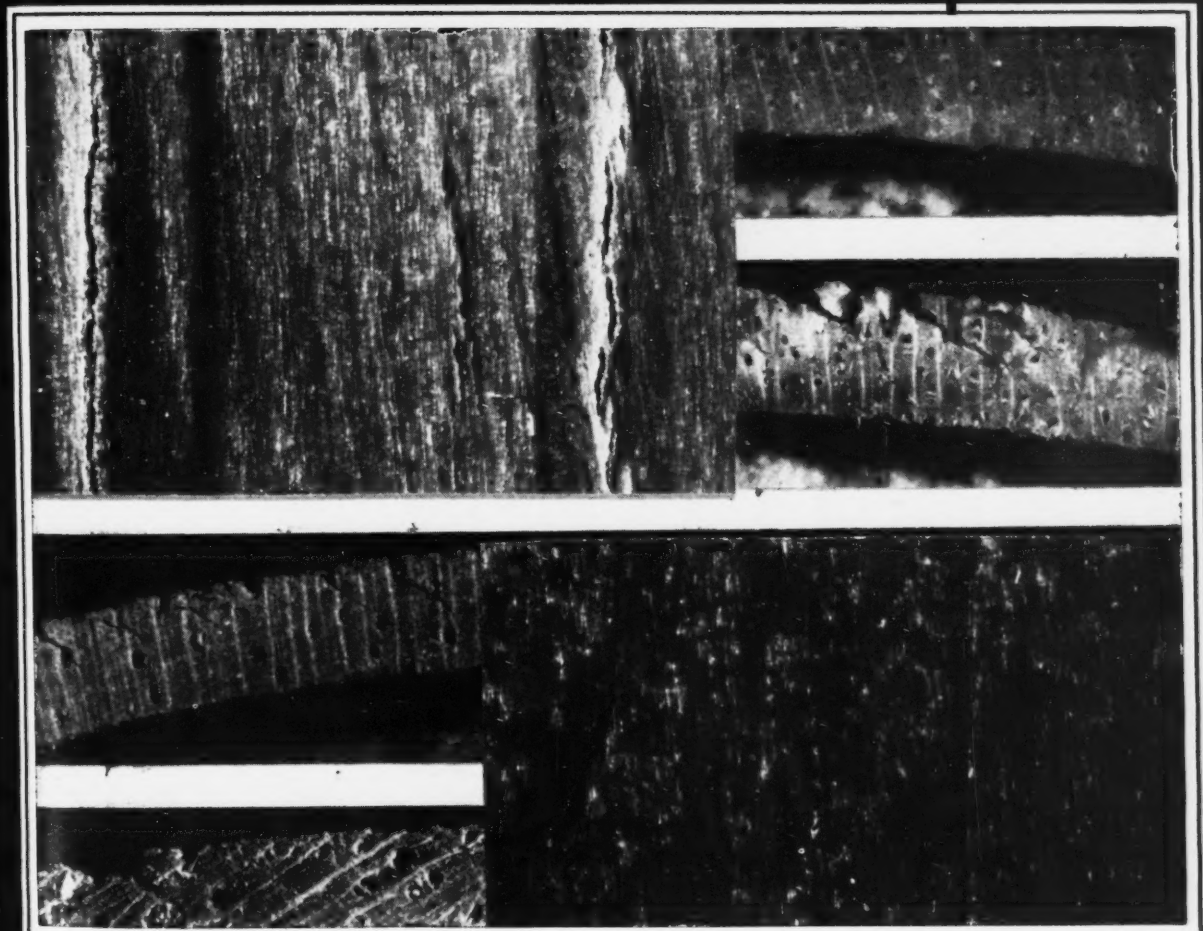
Journal of the Forest Products Research Society



Student Research Relates Face Veneer Quality to Finish Checking. Magnifications illustrate tests . . . Page 7

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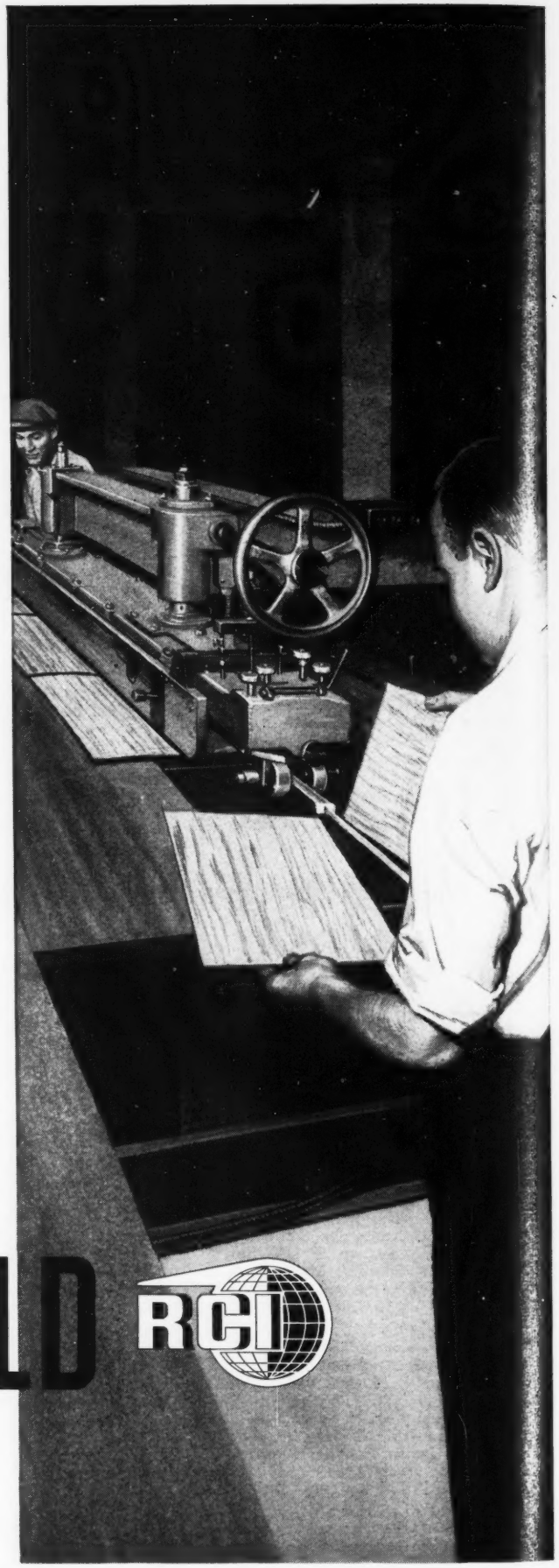

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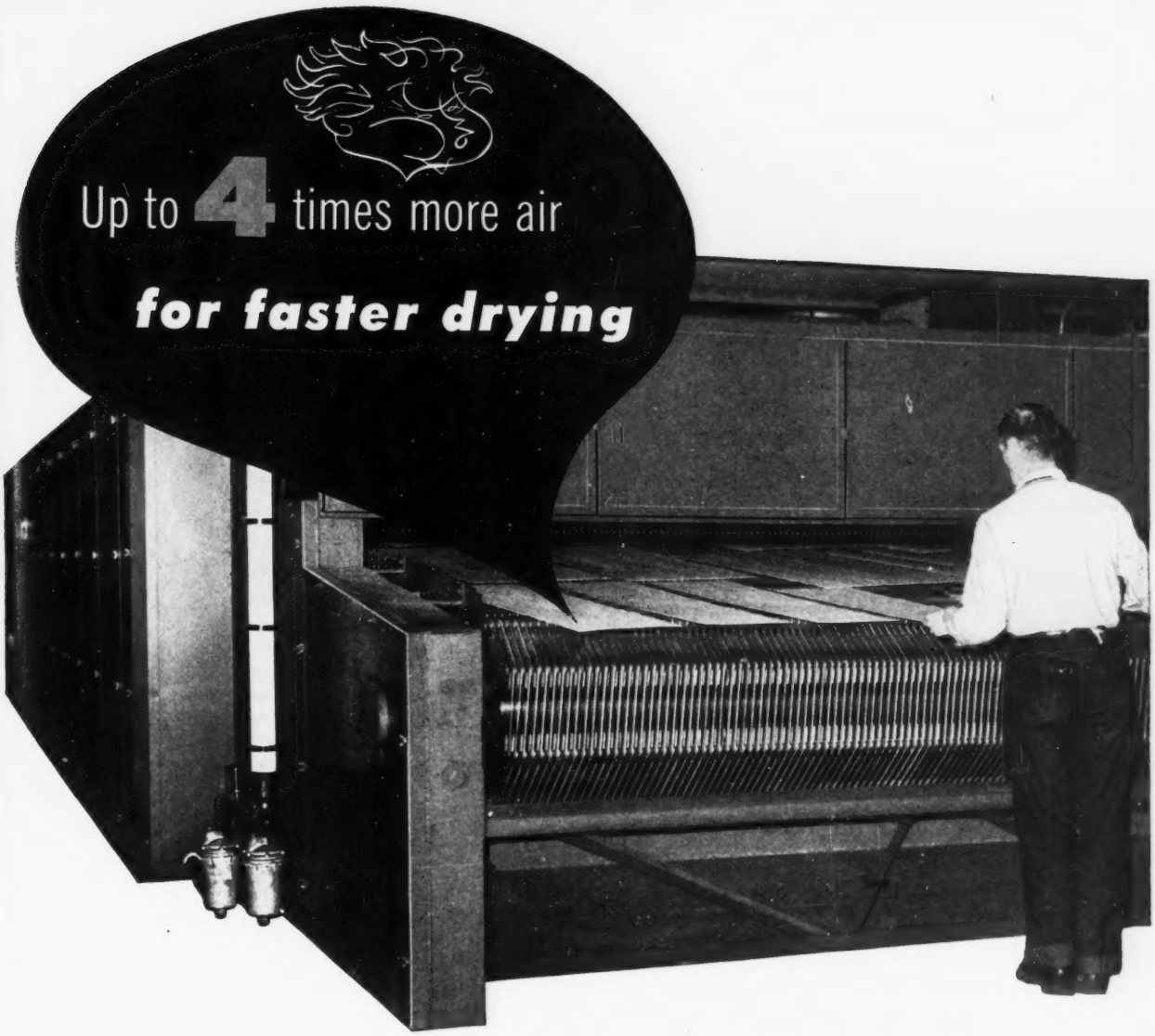

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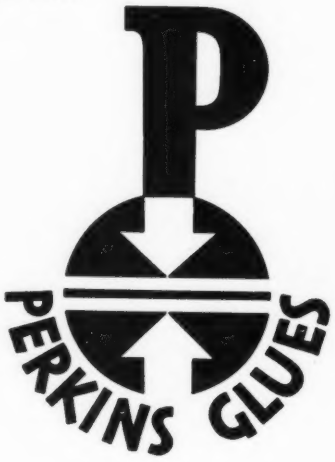

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Vol. III, No. 3 September, 1953

Forest Products Education—A Report and Challenge—*A Guest Editorial*

IT WOULD BE DIFFICULT to outline briefly the many facets to education in the field of forest products technology. Primarily the curricula or programs at the various schools are designed to prepare graduates to fulfill a useful purpose in forest industries, or in governmental or other research. Regional variation in the needs of industry have resulted in programs that differ for the various sections of the country. There is general agreement on the basic core of discipline, particularly chemistry, physics, and mathematics, as well as fundamentals of wood anatomy and properties.

Proficiency in the use of written and spoken English is a constant and repeated plea from employers everywhere. To impress the student with the necessity for this is one of the most difficult instructional problems. The requirement of proficiency in English is about the only one upon which employers are unanimous. Beyond this point agreement ceases, mainly because industries vary in character regionally and individually. Many employers recognize that their specific techniques cannot be taught at the university level without the introduction of a bewildering array of technique courses to take care of the requirements of different industries. It is generally agreed that more is accomplished when the student is provided with a thorough grounding in basic sciences, is taught to think for himself, to be self-reliant, to apply himself to his problems, to express himself clearly to his juniors and superiors, and to get along with those whom he contacts. In acquiring this training, it is essential that he learn as much as possible about wood as a material with many and varied uses.

It is unlikely and indeed undesirable that all schools provide a curriculum of uniform course content. State supported schools have a responsibility to industries from a particular region. Western schools, for example, are more likely to emphasize primary manufacture of softwood species, whereas their eastern counterparts would stress secondary manufacture of both softwoods and hardwoods. Certain schools have programs supported by industry, such as the furniture industry, or the pulp and paper industry. These schools design their programs to meet the needs of such industries. Others are only graduate in character, and train students for national and international placement.

Aside from curriculum content and the actual training of students, several major problems exist in the field of education. These may be summarized as that of 1. encouraging suitable men to enter the field of forest products, 2. acquainting employers with the type of man available and his training, and 3. of providing the graduate with a title whose name is significant.

The problem of encouraging suitable men to enter the field of forest products technology is one that requires immediate attention from the schools and from the Society itself. J. B. Grantham, Director of the Oregon Forest Products Laboratory, at the Memphis meeting of the Committee on Education, drew attention to the fact that young men are not aware of the training offered in forest products nor of the opportunities available in the forest products industries. This is true in particular of high school students. Several of the forest schools have produced brochures illustrating their facilities for training men to enter the various aspects of forestry and forest-products technology. Many do contact work with the high schools, a time-consuming process. These are creditable efforts, but the Committee on Education believes that the Society itself should sponsor a brochure on a national level, to acquaint high school students and others with the opportunities for technical training in preparation for a career in the forest products industries. This would be a major undertaking, requiring the cooperation of the schools, industry, and the Society.

Scholarships set up by various companies offer encouragement to those entering the field. It is to be hoped that many more are initiated for high school graduates and university graduates and undergraduates. Of a similar nature, affording encouragement to students at the university senior and graduate level, as well as acquainting industry with the quality of men available, are the annual awards made under the Wood Award Competition. This issue of the Journal carries three papers that were submitted as entries to this competition. Their high calibre attests to the general level of the papers available from graduate and undergraduate students, and to the fact that although insufficient men are entering the field, those who have entered are superior material.

The problem of acquainting employers with the type of trained man available rests squarely with the schools, and, since it is a national problem, with the Society. Universities cannot operate as trade schools, yet their training programs can be arranged to give students a maximum insight into the problems of and functioning of the wood products industries. Therefore cooperation between the two parties is necessary, and is indeed being established on a sound basis. As industry becomes better acquainted with the potentialities of professionally-trained forest-products technologists the opportunities for such men will greatly expand.

Some educators are concerned with the fact that graduates from our forest products curricula have no universal or distinctive title. The training programs themselves are so diverse that the graduates may be in one of several categories. Programs fall mainly into those specializing in wood technology and those in what could be termed wood engineering. Others may combine both, whereas some stress sales and other aspects. Although it would be desirable to have uniformity in the title of forest-products graduates, the problem is not yet solved. It is probably of less importance than the two primary problems outlined above, that of attracting men and of expanding their opportunities.

The Society has done much to bring the problems of education before those persons most concerned. There is active cooperation between the Society, the schools and industry. As time passes, through the activity of the membership, the profession of forest-products technology or whatever names are adopted, will become recognized as a senior profession.

—*W. W. Wellwood*

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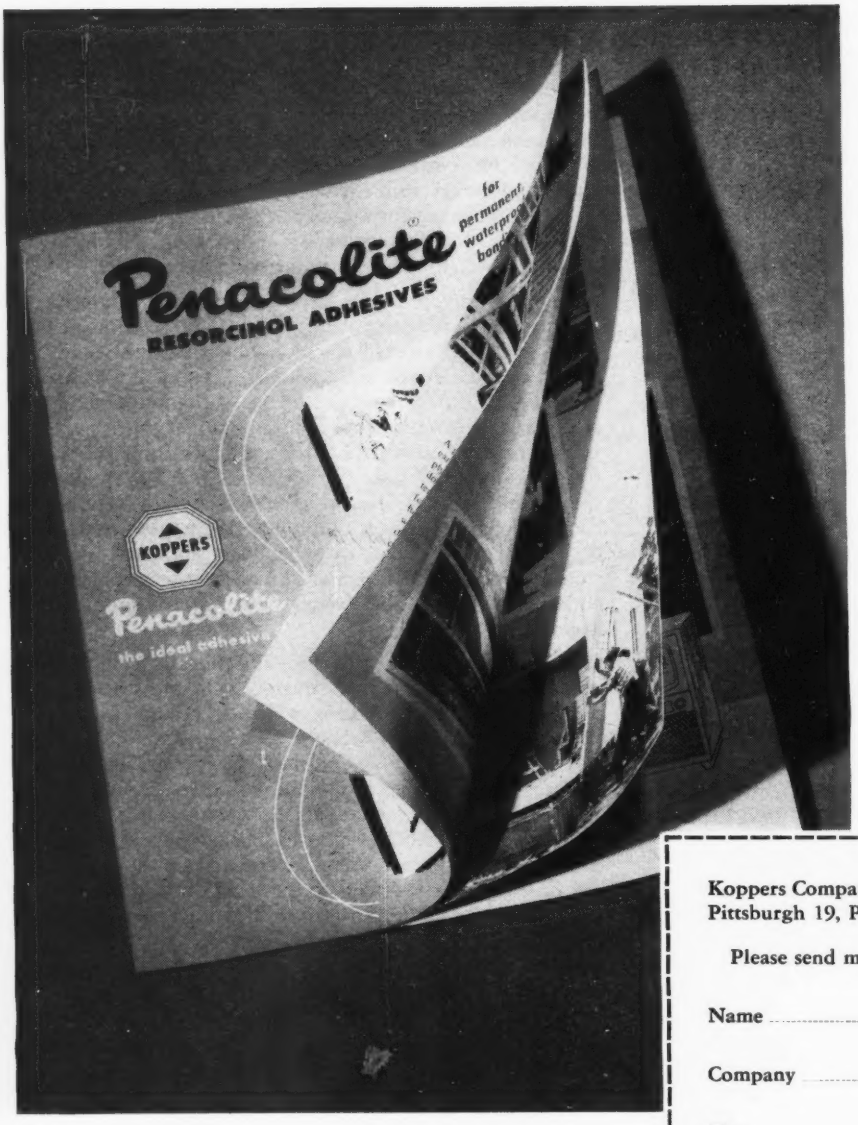

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Finish Checking of Hardwood Veneered Panels as Related to Face Veneer Quality*

BEN A. JAYNE

Graduate student, Yale University School of Forestry, New Haven, Conn.

Study to determine influence of face veneer quality on finish checking is reported. Methods of testing as well as results are described, with conclusion being reached that finish checks due to knife marks may be either minimized or completely eliminated.

THE FINISH CHECKING of hardwood veneered furniture panels is a phenomenon long observed by manufacturers as well as consumers of veneered products. It has been observed with all species and various types of finish. Finish checking has not been restricted to the veneered furniture of any particular section of the country, but has occurred over a wide range of geographic and climatic conditions. In some cases checking occurs within a few days after finish application; in others, its appearance may be delayed until a year or more after the product has been placed in service. Although many types of finish checks are recognized, this paper is concerned only with those that seem to be associated with the characteristics of the face veneer and specifically with the determination of the influence of face veneer quality on finish checking.

Fig. 1 is a magnified surface view of a commercially manufactured, plain-sliced black walnut veneered night stand finished with a high grade lacquer. Finish checks are elongated in a direction parallel to the grain of the face veneer. A cross section of this same panel showed these finish checks to stem directly from knife checks in the face veneer. Several commercially manufactured panels of various types of construction, representing different veneer species and cutting methods and several types of finish were examined. In all cases finish checks were directly traceable to lathe or knife checks that must have been present in the face veneer before finish application.

Literature Review

Little relevant information was found in the literature concerning the type of finish checking with which this paper deals, however, a few papers are available that deal with cold check and finish craze.

In a paper dealing with finish checking Holcombe[1] presented several possibilities for this phenomenon. He observed that alternating conditions of high and low humidity were responsible for finish film fatigue and eventual rupture over filled vessels in sliced walnut veneered panels, and between vessels in sliced oak veneered panels. Panels were allowed to reach weight equilibrium in both the high and low humidity cycles. In addition, Holcombe observed that panels assembled with the open face[2] of the veneer exposed exhibited a slightly greater tendency to check finishes than panels assembled with the closed face exposed. Birch and maple veneered panels were not appreciably affected by relatively severe conditions of humidity or heat (140°F), and high grade synthetic varnishes were not as subject to checking as lacquers or low grade varnishes.

Blackwell[3] observed that finish checks usually appear, if at all, within a few days after finish application. He recognized two types of checking: that which occurred at random in the finish running across as well as parallel to the grain, and that which was entirely parallel to the grain and associated with knife checks in the underlying veneer.

Test Variables and Materials

Face veneers of three different species involving two methods of cutting were investigated in this study. These veneers were rotary-cut yellow birch, plain-sliced black walnut, and plain-sliced white oak.

The study was undertaken primarily to determine the effect of veneer quality on subsequent finish checking. In order to investigate this variable thoroughly, two grades of veneer, tight cut and loose cut[4], were employed with either the open or closed faced exposed on the assembled panel.

In order to simulate as nearly as possible the materials used in furni-

* Entered in Graduate Division, 1953 Wood and Wood Products Award Contest.

[1] Holcombe, R. A. "Surface Checking in Furniture Panels." *Journal Forest Products Research Society*, Vol. II, No. 5: 122–127. December 1952.

[2] As veneer is peeled from a log or sliced from a flitch, checks occur on the knife side as a result of shearing stress as the veneer deflects over the knife. The face from which the checks originate is referred to as the open face.

[3] Blackwell, Richard. "Checks in the Finish of Veneered Surfaces." *Industrial Finishing* 23 (8): 78–81. 1947.

[4] Tight and loose cut refer to knife check depth. The checks of a loose-cut veneer are deeper than those of a tight-cut veneer, but not necessarily more numerous.

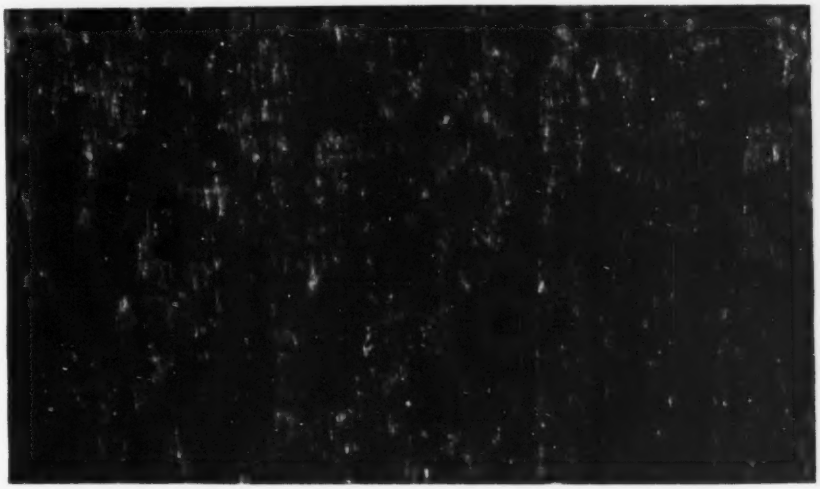


Figure 1.—Surface view of a checked lacquer finish on a commercially manufactured night stand faced with plain-sliced black walnut. (20X)

ture manufacture, two typical finishes were used. A synthetic alkyd-urea varnish of 38 percent solids content at time of application was applied to the walnut and birch veneered panels. The second finish, a high grade lacquer of 24 percent solids content at time of application, was applied to the oak as well as to the walnut and birch veneered panels.

Half of the test specimens were given a relatively heavy sanding and half a relatively light sanding in order to determine the effect of depth of sanding on subsequent finish checking. In addition, the effect of a filler was studied since a previous investigation[5] indicated that this variable had some influence on finish checking. Although birch is not considered an open-grained wood, and therefore is not commonly filled, a portion of the birch as well as of the walnut and oak veneered panels was filled before finish application to permit a broader basis for the study of this variable.

A total of 34 (10 x 30 in.) lumber-core plywood panels were assembled and later cut to test specimens 10-in. wide and 5-in. long before sanding and finish application. Fig. 2 illustrates a typical panel and the matching of its component test specimens. Ten of the 34 panels were faced with 1/28-in. rotary-cut yellow birch, 16 with 1/28-in. plain-sliced black walnut, and eight with 1/28-in. plain-sliced white oak. These veneers were selected from a large group of commercially cut stock to represent a wide range of veneer quality from the standpoint of tightness of cut. Core stock of either basswood or aspen ranged from 0.6 to 0.9 in. in thickness, and crossbands were of 1/16-in. rotary-cut basswood or 1/20-in. rotary cut yellow poplar. The backs of all panels were 1/28-in. rotary-cut yellow birch.

[5] Holcombe, op. cit., p. 127.

Veneer Selection

The tightness or looseness of cut of face veneers was determined by observing the depth of checks visible on a smoothly cut end-grain surface of each veneer sheet. A method described by Limbach[6] involving ink penetration of knife checks for accurate measurements of their depth was employed successfully.

Birch veneers exhibiting a check depth of 1/8 to 1/4 veneer thickness, measured in a direction normal to the veneer face, were classified as tight cut. A limited number of birch veneers with a check depth ranging between 1/2 and 3/4 veneer thickness were available and were classified as loose cut. Typical txamples of these tight- and loose-cut face veneers are illustrated in Figs. 3–A and 3–B respectively.[7]

Such a definite demarcation between tightness and looseness of cut was not possible with the sliced walnut veneers available for the study. Veneers exhibiting checks of a depth (measured normal to the surface) of less than half the veneer thickness were considered tight cut, while those exhibiting a check depth greater than half the veneer thickness were classified as loose cut. However, the greater portion of the checks in the tight-cut veneers were within the limits of 3/8 to 1/2 veneer thickness while the greater portion of checks in the loose-cut veneers were within the limits of 1/2 to 5/8 veneer thickness. Typical examples of these close limits are illustrated in Figs. 3–C and 3–D illustrating tight- and loose-cut veneers respectively. Fig. 3–E illustrates a typical example of an extremely loose-cut sliced walnut veneer. Checks in this particular veneer reached an average depth of 3/4 veneer thickness measured in a direction normal to the veneer face.

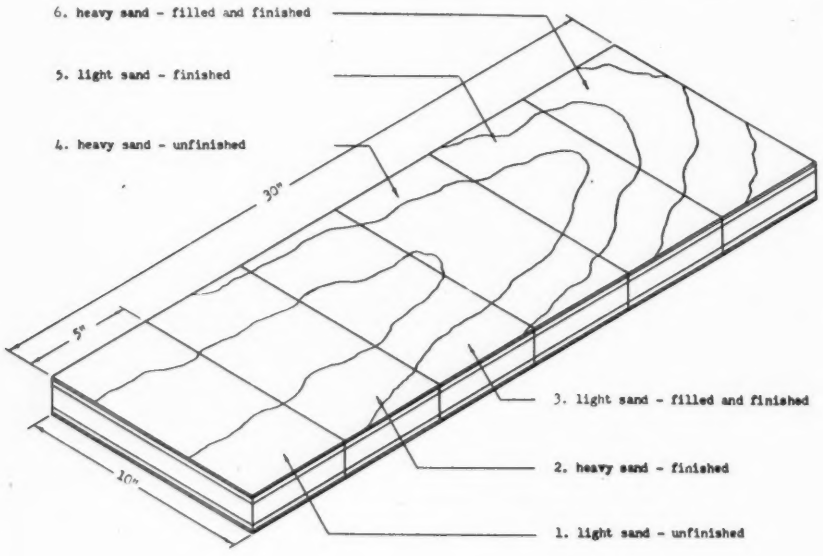
The knife checks in veneers of the three categories tended to follow the wood rays and consequently were slightly deeper in areas where checks and rays were approximately parallel.

The sliced oak veneers used for the study were somewhat similar to the walnut veneers in check depth variation. A check depth of less than half the veneer thickness classified the veneer as tight cut, while a check depth greater than half the veneer thickness classified the veneer as loose cut.[8] Check depth in the oak veneers was for the most part within the relatively close limits of 1/4 to 1/2 veneer thickness in the tight-cut category and 1/2 to 3/4 veneer thickness in the loose-cut category. Typical examples of these two categories are illustrated in Figs. 3–F and 3–G of tight- and loose-cut veneers respectively.

The deep knife checks parallel to the wood rays observed in both tight- and loose-cut veneers of sliced oak and walnut were present only toward one edge of the open face of each plain-sliced veneer sheet.[9] These checks, as mentioned previously, penetrated very deeply in the oak veneers, but exhibited only a slight increase in depth in the walnut veneers.[10]

[6] Limbach, J. P. "A Method of Measuring Checks in Veneer." *Journal of Forestry*, 44 (7): 509–511. July, 1946.

[7] This photograph and the following ones of this type were taken with a sample veneer strip bent around a cork of 2-in. diameter.


6. heavy sand - filled and finished
5. light sand - finished
4. heavy sand - unfinished
30"
5"
10"
3. light sand - filled and finished
2. heavy sand - finished
1. light sand - unfinished

Legend:

Light sand - removal of .007 to .011 in. of face veneer
Heavy sand - removal of .016 to .020 in. of face veneer

Figure 2.—Veneered panel and its component test specimens.

Panel Preparation

Before panel assembly, lumber cores were conditioned to a moisture content of 8 percent in a humidity-controlled cabinet operating at a temperature of 140°F. Face and back veneers as well as crossbands were conditioned to a moisture content of 6 percent in one day under conditions

[8] Only knife checks that were not parallel to the wood rays were considered in the classification of oak veneers, since in areas where the slope of checks and rays was approximately equal the checks penetrated to 7/8 veneer thickness or more in depth in both the tight- and loose-cut categories.

[9] Wood ray slope, as observed on the end section of a plain-sliced veneer, may vary from approximately a 45° slope at one edge of the veneer sheet to an equal and opposite slope at the other edge. Therefore knife checks can follow the rays in an area at one edge of the veneer only and will run across the rays in the other areas of the veneer.

[10] The effect of these deep knife checks on subsequent finish checking is taken up at length in the results.

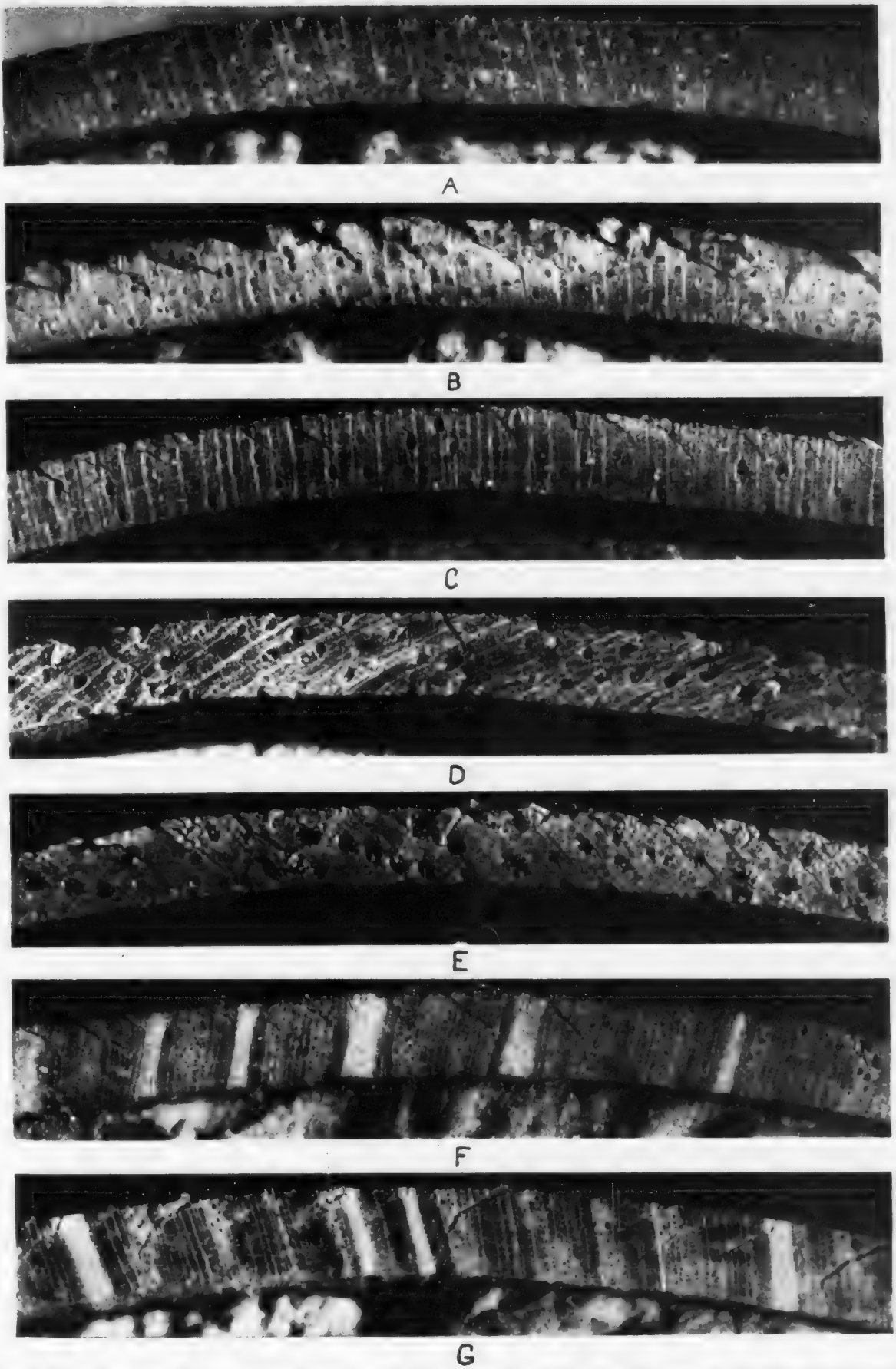


Figure 3.—Cross sections of representative veneers used in the study. A. tight-cut, 1/28-in., rotary-cut yellow birch veneer. B. loose-cut, 1/28-in., rotary-cut yellow birch veneer. C. tight-cut, 1/28-in., plain-sliced black walnut veneer. D. loose-cut, 1/28-in., plain-sliced black walnut veneer. E. extremely loose-cut, 1/28-in., plain-sliced black walnut veneer. F. tight-cut, 1/28-in., plain-sliced white oak veneer. G. loose-cut, 1/28-in., plain-sliced white oak veneer. (20X)

of 40 percent relative humidity at a temperature of 140°F. Bonding was accomplished with a room-temperature setting urea-formaldehyde resin in a screw-type press delivering 150 p.s.i.

Each (10 x 30 in.) panel was divided into six test specimens (10 x 5 in.) as illustrated in Fig. 2. Specimens of this size were sanded in a Sheboygan endless bed drum sander with the following abrasives:

Drum no.	Grit size
1	36 aluminum oxide
2	60 aluminum oxide
3	180 aluminum oxide

Heavily sanded specimens were obtained by taking very light cuts on the No. 1 and No. 2 drums, removing from .016 to .020 in. of the face veneer. Lightly sanded specimens were obtained by taking very light cuts on the No. 2 and No. 3 drums, removing from .008 to .010 in. of the face veneer. This schedule removed approximately ½ the face veneer thickness of the heavily sanded specimens and ¼ the face veneer thickness of the lightly sanded specimens.

A producer of high quality veneered furniture cooperated in applying the two finishes required for the study. The schedule for finishing of unfilled specimens with the synthetic alkyd-urea varnish was as follows:

1. One coat of non-stearated sealer of 18 percent solids with a film thickness of .0011 in.
2. Scuff sanded with silicon carbide, 220 grit, "A" weight, finishing paper.
3. One coat of alkyd-urea varnish of 38 percent solids with a film thickness of .0022 in.
4. Force dried 4 hours at 116°F and 30 percent relative humidity.

The filled specimens were finished in the same manner described above after application of a wash coat of negligible film thickness, scuff sanding as described in step No. 2 above, and application and drying of the walnut colored filler (mineral spirits soluble). This synthetic varnish finish was applied to panels veneered with birch and walnut of the qualities illustrated in Figs. 2–A, 2–B, 2–C, and 2–D respectively.

The schedule for finishing of unfilled specimens with the high grade lacquer was as follows:

1. One coat of non-stearated sealer of 23 percent solids and a film thickness of .001 in.
2. Scuff sanded with silicon carbide, 220 grit, "A" weight, finishing paper.
3. One coat of lacquer of 24 percent solids and a film thickness of .002 in.
4. Air dried 24 hours at 75°F and 20 percent relative humidity.

The filled, lacquered specimens were finished by the same schedule shown above after application of a wash coat of 7 percent solids content with negligible film thickness, scuff sanding as described in step No. 2 above, and application and drying of a natural filler (mineral spirits soluble). This lacquer finish was used on specimens veneered with sliced walnut of the qualities illustrated in Figs. 2–C and 2–E, rotary-cut birch of the quality illustrated in Fig. 2–A, and sliced oak of the qualities illustrated in Figs. 2–F and 2–G.

After finishing, all test specimens were given three separate edge coatings of Angier log sealer[11] to prevent any rapid loss or gain of moisture by end-grain surfaces. Specimens edge coated in this manner could then be likened to small sections of large veneered surfaces when subjected to test cycles.

Testing

Test conditions were selected in an effort to duplicate as nearly as possible under an accelerated schedule, the seasonal moisture variations encountered in interior woodwork in many parts of the United States.[12] Test specimens were subjected to some or all of 15 complete cycles of high and low humidity to simulate these conditions. The 15 test cycles were as follows:

1. A high humidity half cycle at a relative humidity of 80 percent and temperature of 110°F for eight days followed by a low humidity half cycle at a relative humidity of 28 percent and a temperature of 110°F for eight days. Specimen moisture content was found to vary between 5 and 13 percent during the course of the cycle.
2. A high humidity half cycle at a relative humidity of 80 percent and temperature of 100°F for 48 hours followed by a low humidity half cycle at a relative humidity of 20 percent and a temperature of 100°F for 48 hours. Face veneer moisture content was found to vary between 5 and 10.5 percent during the course of this cycle and the following four cycles.
3. Same as No. 2.
4. Same as No. 2.
5. Same as No. 2.
6. Same as No. 2.
7. An aging period at a relative humidity of 11 percent and a temperature of 105°F for six weeks.
8. A high humidity half cycle at a relative humidity of 80 percent and a temperature of 100°F for 72 hours followed by a low humidity half cycle at a relative humidity of 20 percent and a temperature of 100°F for 72 hours. Face veneers of the test specimens were observed to vary between 5 and 11 percent during the course of this cycle and the following seven cycles.
9. Same as No. 8.
10. Same as No. 8.
11. Same as No. 8.
12. Same as No. 8.
13. Same as No. 8.
14. Same as No. 8.
15. Same as No. 8.

Testing of specimens was conducted in a temperature- and humidity-controlled cabinet in which the desired conditions could be maintained. At the completion of each half cycle, moisture content of face veneers was determined by oven-drying sections of sample panels. Test specimens were examined under low angle lighting at the completion of each half cycle. Any specimen exhibiting surface irregularities was examined on the smoothly cut end-grain surface of the face veneer.

Results

Birch Veneered Panels: The birch-veneered test specimens finished with the synthetic varnish were subjected to Cycle Nos. 1 through 15. At the end of two days exposure to the high humidity half of the first cycle, test specimens faced with loose-cut veneers[13] exhibited surface irregularities that took the form of long ridges running parallel to the grain of the veneer.

The ridges were most numerous in those specimens assembled with the closed face of the veneer exposed and given a heavy sanding and in those specimens assembled with the open face of the veneer exposed and given a light sanding. The remaining test specimens faced with loose-cut veneers developed extremely few ridges whether assembled with the closed face of the veneer exposed and given

[11] Angier log sealer No. SB–525, this is a sealing compound manufactured by Angier Products Inc.

[12] Peck, E. C. "Moisture Content of Wood in Use." For. Prod. Lab. Rept. 1655, Madison, 1950.

[13] Illustrated in Fig. 2–B.

a light sanding or assembled with the open face of the veneer exposed and given a heavy sanding. After six additional days of exposure, completing the high humidity half of the first cycle, the ridges became much more prominent both in height and length. Sections cut at this time exposing the end-grain surface of the face veneer revealed that the ridges in the finish occurred directly over lathe checks in the face veneer.

At the completion of two days exposure to the low humidity half of the first cycle the ridges in the finish of panels faced with loose-cut veneers developed into finish checks. A cross-sectional surface of a typical finish-checked loose-cut birch veneered specimen is illustrated in Fig. 4.[14] This particular specimen was assembled with the closed face of the veneer exposed. Lathe checks, exposed on the surface of the veneer by a heavy sanding, were responsible for development of checks in the finish. In all cases checks in the finish of specimens faced with loose-cut birch veneers were directly traceable to lathe checks in the face veneer.

After exposure to Cycle Nos. 1 through 15, test specimens faced with tight-cut veneers[15] and finished with the synthetic varnish remained entirely free of finish checks whether assembled with the open or closed face exposed or given a light or heavy sanding. A cross section of a typical specimen assembled with the open face of a tight-cut veneer exposed and given only a light sanding is illustrated in Fig. 5. There are no lathe checks or finish checks visible in this cross section.

The same general behavior described in the preceding paragraph was observed with specimens faced with tight-cut birch veneers and finished with the lacquer. Regardless of the variables of construction, these panels remained entirely free of finish checks after exposure to Cycle Nos. 8 through 15.

In no case was the action of filler in exposed vessels of the face veneer observed to be responsible for the development of finish checks.

Oak Veneered Panels: Sliced oak veneered test specimens were finished only with the lacquer and were subjected to Cycle Nos. 8 through 15. Seventy percent of the test specimens had developed minute ridges parallel to the grain of the face veneer at the

[14] Sections of this type were prepared by dampening the surface and allowing it to dry. This caused the knife checks to open slightly for better observation, but in no case was responsible for the development of additional finish checks.

[15] Illustrated in Fig. 3-A.

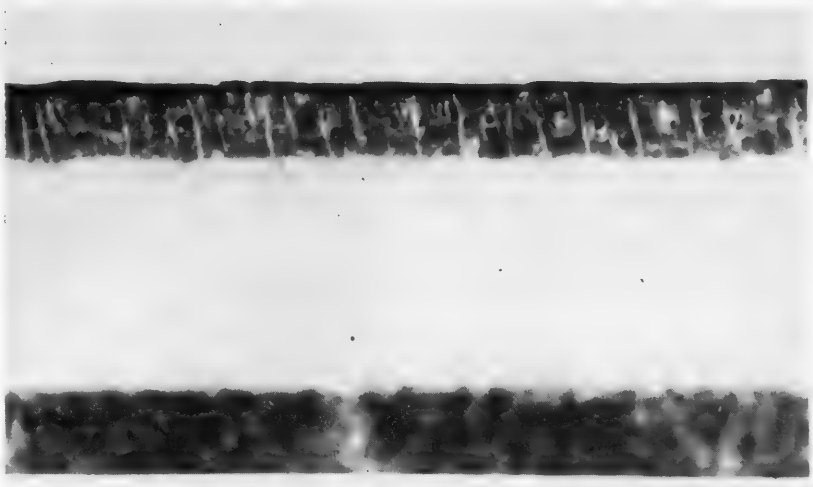


Figure 4.—Cross section of a specimen faced with a loose-cut birch veneer having the closed face exposed and given a heavy sanding. The varnish finish is checked. (20X)

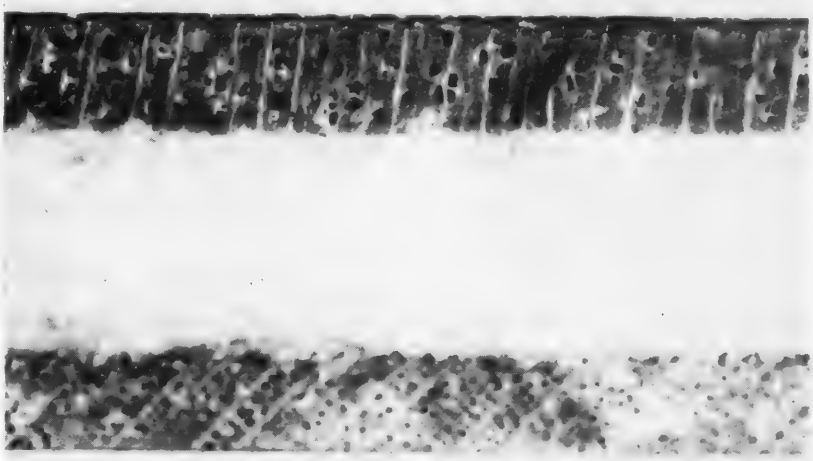


Figure 5.—Cross section of a tight-cut birch veneered specimen assembled with the open face exposed and given a light sanding. No knife checks or finish checks are visible. (20X)

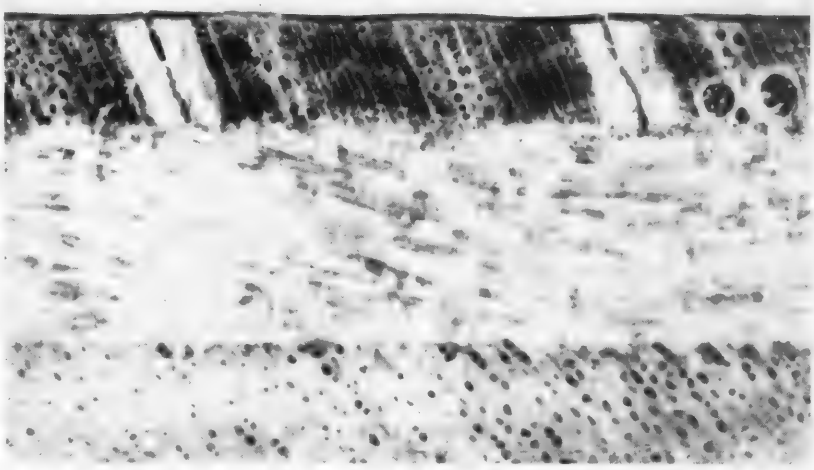


Figure 6.—Cross section of a checked lacquer finish on a specimen faced with a tight-cut oak veneer in an area where knife checks and wood rays are parallel. The specimen was assembled with the closed face of the veneer exposed and given a light sanding. (20X)

completion of the high humidity half of Cycle No. 8. On a cross section exposing the end-grain surface, these ridges were observed to occur directly over knife checks in the face veneer.

At the end of the low humidity half of this cycle, the ridges previously observed had developed into finish checks. At the completion of the low humidity half of Cycle No. 10, every test specimen had developed finish checks in some portion of the panel face.

Regardless of the variables of construction of the test specimens, checks occurred in the finish of every specimen over that portion of the face veneer in which knife checks and wood rays were approximately parallel. In every instance these finish checks were observed to occur directly over knife checks in the face veneer. Checks of this type in the finish of a specimen assembled with the closed face of a tight-cut veneer exposed and given a light sanding are illustrated in cross section in Fig. 6.

Checks in the finish of specimens faced with tight-cut veneers,[16] in sections of the face veneer where knife checks and wood rays were not parallel, were confined for the most part to those specimens assembled with the open face of the veneer exposed and given a light sanding. Surface and cross-sectional views of a test specimen of this type are illustrated in Figs. 7 and 8 respectively.

Specimens assembled with the open face of a tight-cut veneer exposed and given a heavy sanding were free of finish checks in comparable areas of the face veneer. Fig. 9 illustrates in cross section a typical specimen of this type. In addition, test specimens assembled with the closed face of a tight-cut veneer exposed and given a light sanding developed no finish checks over areas of the face veneer where knife checks and wood rays were not parallel. Finish checking in comparable areas of specimens of similar assembly which were given a heavy sanding were present in minor numbers.

On the other hand, both lightly and heavily sanded specimens assembled with the open face of loose-cut veneer[17] exposed developed finish checks even in areas where knife checks and wood rays were not parallel. The frequency of finish checks occurring in the heavily sanded specimens, however, was somewhat less than that occurring in the specimens given a light sanding. Specimens assembled with the closed face of a loose-cut veneer exposed also developed finish checks in areas where knife checks and wood rays were not parallel if given a heavy sanding. A light sanding of specimens of similar construction, however, exposed relatively few knife checks and finish checking was minimized.

[16] Illustrated in Fig. 3–F.
[17] Illustrated in Fig. 3–G.

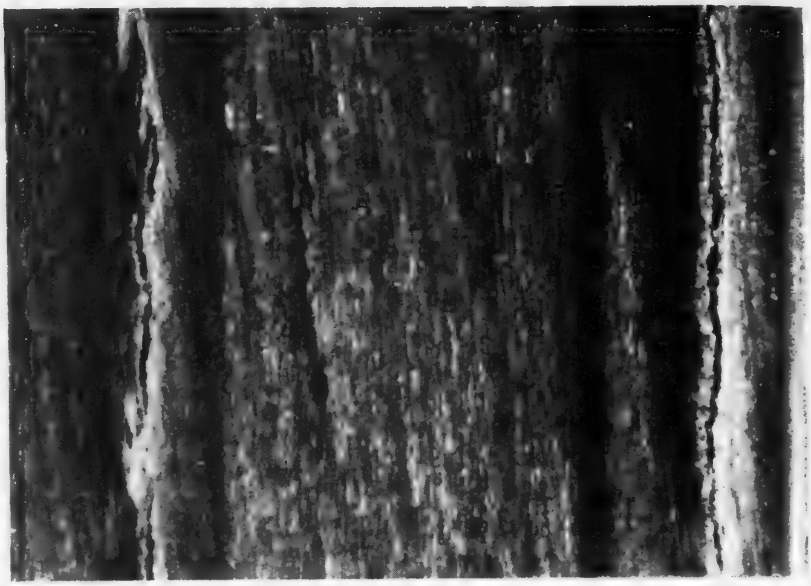


Figure 7.—Surface view of a checked varnish finish on a specimen faced with a tight-cut oak veneer having the open face exposed and given a light sanding. (20X)

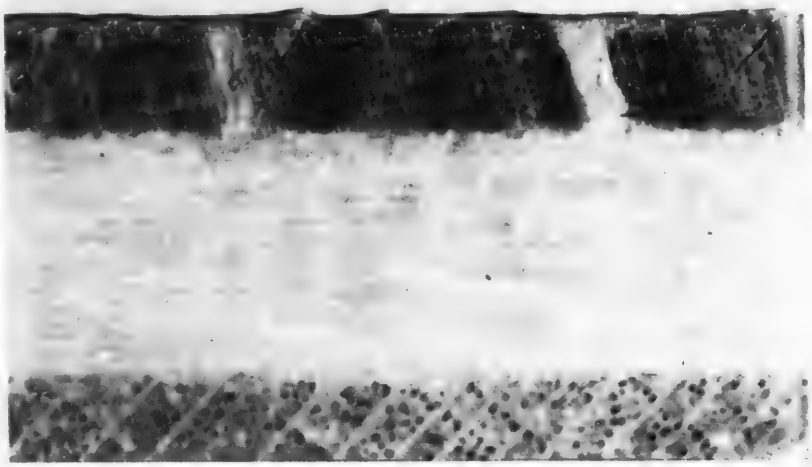


Figure 8.—Cross section of the specimen illustrated in Fig. 7. (20X)

The majority of finish checks by far were directly traceable to knife checks in the face veneer of test specimens. In a relatively few cases a finish check was observed to occur over a large exposed vessel at the veneer surface. These were extremely few in number and comprised but a small portion of the total number of finish checks in the oak specimens.

Filled test specimens developed a sunken condition in the finish film over exposed filled vessels at the end of low humidity half cycles. At the completion of high humidity half cycles, no extreme swelling of the filler to develop ridges in the finish was observed, although the sunken condition was slightly relieved. In no case, however, was this slight swelling and shrinking of the filler in exposed vessels observed to be responsible for the development of finish checks in these test specimens.

Walnut Veneered Panels: Finish checks which occurred in this group of panels were traceable to two causes. Knife checks in the face veneer were by far responsible for the greatest portion of checks occurring in either type of finish over tight- or loose-cut face veneers. The second cause, which constituted a relatively small number of finish checks, was traceable to an occasional large exposed vessel or a large vessel immediately beneath the veneer surface. This discussion of results will be mainly concerned with finish checks occurring over knife checks in the face veneer.

Specimens faced with tight-cut veneers similar to the quality illustrated in Fig. 3–C were finished with both the synthetic varnish and lacquer. Since the character of checking occurring in either finish of this group of specimens was essentially the same, a discussion of causes will combine both finishes. No direct comparison of the relative check resistance of the two finishes will be made, however, since the test conditions employed for each finish were not comparable.

The tight-cut veneered specimens finished with the synthetic varnish were subjected to Cycle Nos. 1 through 15. Finish checking was observed after the completion of Cycle No. 4. Lacquer finished specimens of comparable face veneer quality were exposed to Cycle Nos. 8 through 15 and developed finish checks after the completion of Cycle No. 12.

Although the surface appearance of the checks in either finish did not appear to grow appreciably worse after several additional cycles of exposure, the number of checks in the finish of each specimen increased with each succeeding cycle. The relatively small amount of checking that did occur in the finish of tight-cut veneered specimens was confined, for the most part, to areas where knife checks and wood rays were parallel in the face veneers; these specimens had been assembled with the closed face exposed and given a heavy sanding or with the open face exposed and given a light sanding. In the first case a heavy sanding was responsible for exposing knife checks which were parallel to the wood rays and therefore slightly deeper than other checks in the veneer. In the second case a light sanding failed to remove enough of the deeper checks parallel to the rays to control checking. Consequently, finish checks occurred over each knife check exposed on the face veneer surface. Other knife checks which were not parallel to the rays were occasionally responsible for finish checks in specimens of similar construction, but this was the exception rather than the rule.

Specimens faced with tight-cut veneers assembled with the closed face exposed and given a light sanding or with the open face exposed and given a heavy sanding developed practically no finish checks whatsoever. Knife checks were not exposed by the light sanding of the closed face and were removed by a heavy sanding of the open face of the veneer.

Specimens faced with loose-cut veneers similar to the type illustrated in Fig 3–D were finished with the synthetic varnish and subjected to Cycle Nos. 1 through 15. Finish checks appeared after completion of Cycle No. 4 and increased in number in each checked specimen with each succeeding cycle. Checks were most prevalent in the finish of those specimens assembled with the closed face of the loose-cut veneer exposed and given a heavy sanding or specimens assembled with the open face of similar veneers exposed and given a light sanding. In the first case knife checks were exposed on the veneer face by a heavy sanding and in the second a light sanding failed to remove knife checks exposed by the method of assembly. In both cases checks in the finish occurred directly over knife checks in the face veneer. Although finish checks were slightly more severe and numerous over areas of the face veneer where knife checks and wood rays were approximately parallel, they were not necessarily restricted to these areas as was observed in the case of tight-cut veneers.

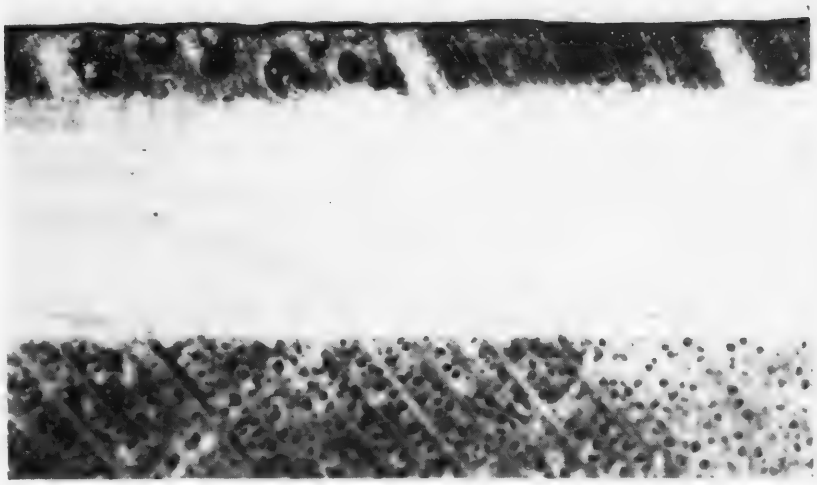


Figure 9.—Cross section of a tight-cut oak veneered specimen assembled with the open face exposed and given a heavy sanding. No knife checks or finish checks are visible. (20X)

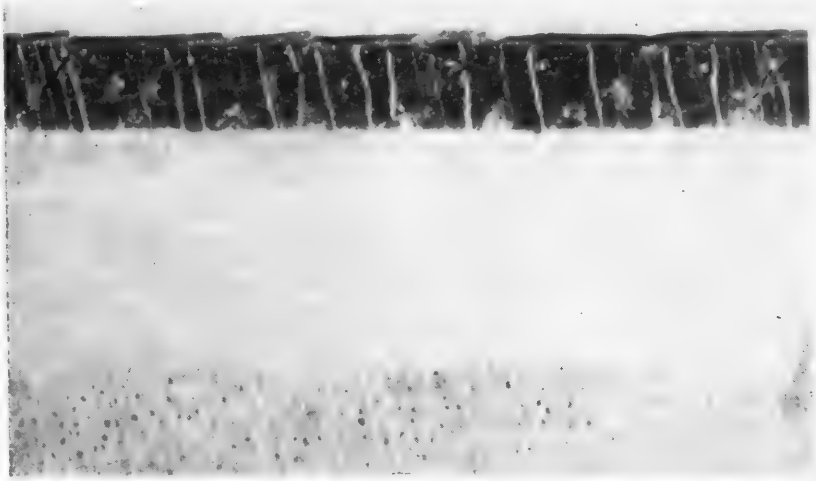


Figure 10.—Cross section of a specimen faced with an extremely loose-cut walnut veneer having the closed face exposed and given a light sanding. The lacquer finish is checked. (20X)

A heavy sanding of specimens faced with loose-cut veneers having the open face exposed or a light sanding of specimens assembled with the closed face of veneers of similar quality exposed was responsible for controlling subsequent finish checking to some degree. A heavy sanding practically removed knife checks exposed by the method of construction in the former case while a light sanding did not remove sufficient material from the closed face of the latter to expose a large number of knife checks.

Specimens faced with extremely loose-cut veneers similar to the type illustrated in Fig. 3–E were finished with the lacquer and subjected to Cycle Nos. 8 through 15. Checks appeared in the finish of all specimens regardless of the variables of construction after completion of Cycle No. 12. Specimens assembled with the open face of the veneer exposed developed finish checks whether given a light or heavy

sanding, however, checking was more severe and frequent in those specimens given a light sanding than those given a heavy sanding. Specimens assembled with the closed face of comparable veneers exposed also developed finish checks whether given a light or heavy sanding, but as would be expected from the previous discussion, those given a light sanding developed fewer and less severe finish checks than those given a heavy sanding. A cross-section of a typical finish checked specimen assembled with the closed face of an extremely loose-cut veneer exposed and given a light sanding is illustrated in Fig. 10. These specimens were lacquer finished. In all cases, finish checks were directly traceable to knife checks exposed at the surface of the veneer.

A less frequent type of finish check occurring in both the varnish and lacquer finishes applied to the walnut veneered specimens appeared directly over exposed vessels at the veneer surface or vessels immediately beneath the veneer surface. Evidently, working of wood fibers on either side of vessels with changing moisture contents caused the former finish checks, while the same behavior was responsible for opening a split to the veneer surface in the latter which then operated essentially as a knife check. Although no count was made of the number of checks occurring in the finish of walnut veneered specimens, it can safely be said that knife checks exposed by methods of panel assembly or by a heavy sanding were responsible for at least 90 percent of the finish checks that occurred. In no case was the action of filler in exposed vessels observed to be responsible for the development of checks in either the lacquer or varnish finish.

The severity of finish checking in the walnut veneered specimens was never as pronounced as that observed in either the birch or oak veneered specimens. This difference cannot be attributed to veneer quality since the depth of knife checks, especially in the loose-cut categories, was quite comparable in all three species investigated. An explanation may lie in a comparison of shrinkage values of the three species from a green to oven-dry condition based on green dimensions:

Species	Shrinkage, percent	
	Radial	Tangential
Yellow birch	7.2	9.2
White oak	5.3	9.0
Black walnut	5.2	7.1

Maximum shrinkage which occurs in the tangential plane is seen to be substantially greater in white oak and yellow birch than in black walnut. Since checks in the finish of the veneered specimens can be attributed to a working of the wood on either side of an exposed knife check or vessel, the lower shrinkage value for black walnut may explain the reduced severity of finish checks observed in specimens veneered with this species.

Conclusions

1. Checks in the lacquer or synthetic varnish finish of panels veneered with rotary-cut yellow birch, plain-sliced black walnut, and plain-sliced white oak selected from commercially-cut stock representing a wide range of veneer quality, appeared after being subjected to conditions of alternating high and low humidity. The finish checks were observed to stem from two causes:

   a. knife checks exposed at the veneer surface by the method of assembly or by heavy sanding.
   b. large vessels exposed at the veneer surface or immediately beneath the surface.

Of the two causes, the former were by far more prevalent with veneers of the qualities used in this study, and were responsible for at least 90 percent of the total number of finish checks observed. Checks resulting from the latter were present only in panels faced with walnut and oak veneers and were at the most of minor importance.

2. Checks in the finish of panels faced with *tight-cut veneers* (as defined in this study) may be eliminated by the following combinations of assembly and depth of sanding:

   a. either a light or heavy sanding of birch veneered panels having either the open or closed face of the veneer exposed.
   b. a light sanding of oak and walnut veneered panels having the closed face of the veneer exposed, or a heavy sanding of comparable panels assembled with the open face exposed. In the case of oak the preceding combinations are applicable only to areas of panels in which knife checks run across the wood rays.

3. Checks in the finish of panels faced with *loose-cut veneers* of birch, oak, and walnut may be minimized by a light sanding of panels assembled with the closed face of the veneer exposed or a heavy sanding of panels having the open face of the veneer exposed.

The combinations set forth in the above paragraphs were found to either eliminate or minimize finish checking caused by knife checks. Their principle is that of preventing or minimizing the exposure of knife checks at the veneer surface by controlling the depth of sanding of either the open or closed face.

4. The following combinations of assembly and depth of sanding have been observed to result in large numbers of checks in the finish of veneered panels and are to be avoided if finish checking is to be controlled.

   a. light sanding of loose-cut birch veneered panels having the open face of the veneer exposed or a heavy sanding of comparable panels assembled with the closed face exposed.
   b. a light sanding of tight- or loose-cut oak veneered panels having the open face of the veneer exposed or a heavy sanding of loose-cut oak veneered panels having the closed face exposed.
   c. a light sanding of loose-cut walnut veneered panels having the open face of the veneer exposed or a heavy sanding of comparable panels assembled with the closed face exposed.
   d. either a light or heavy sanding of panels faced with extremely loose-cut veneers as illustrated in Fig. 3-E, assembled with either the open or closed face exposed.

In all cases the conclusions drawn in the preceeding four sections are applicable only to the qualities of veneer and experimental variables used in this study.

5. Knife check depth in plain-sliced veneers is minimized in areas where the checks run across the wood rays and, therefore, have less opportunity to follow the rays and penetrate deeply into the veneer. Checks in the finish of tight cut veneered panels over areas of this type assembled in the manner described in paragraph No. 2 (b) will be eliminated.

6. In no instance was the effect of the filler (mineral spirits soluble) in vessels exposed at the veneer surface observed to be responsible for the development of finish checks, and only in the case of oak veneered specimens was the expansion and contraction of filler with changing moisture contents observed to cause a slight flexing of the finish film.

Summary

An investigation was undertaken to determine specifically the effects of veneer quality (as measured by tightness of cut), assembly methods, depth of sanding, and presence or absence of filler on the subsequent finish checking of lumber core plywood pan-

(Continued on page 91)

A New Method For Observing Gap-Filling of Wood Adhesives[1]

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The art of gluing wood is beset by factors which are largely unassessable because they are uncontrollable in experiments. One of these factors is glue line thickness. Hence, knowledge of the tolerance of glue to glue line thickness is valuable information for proper use of adhesives.

The characteristics of thick glue lines are described in terms of the activity of the adhesive. Factors that must be controlled in a method for observing gap-filling properties are thus defined and reduced to (1) absolute fluid pressure on the adhesive, (2) thickness of the adhesive layer, and (3) rigidity of the bonded members.

A method is described whereby these factors are brought under positive independent control. Data is presented showing the behavior of typical assembly adhesives as they react to the imposed conditions of test. Results appear to indicate that useful criteria of gap-filling properties may be obtained.

DESPITE THE ADVANCES in the chemistry of adhesives, the gluing of wood remains an art in which experience is still the main implement of success. Although there has been progress in the knowledge of both adhesives and wood, the integration of these two fields has not been accomplished with sufficient clarity to achieve a proportionate advance toward making wood gluing a science. There are reasons for this situation.

Not only do voids exist in our basic information about wood, adhesives and adhesion, but, of more practical consequence, we cannot correctly evaluate many of the factors which influence the bonding process. The difficulty in studying the effects of bonding variables is due, in large part, to the difficulty of controlling them in experimental procedures.

A research program, a part of which is reported in this paper, is in progress which indicates the possibility of positive, independent control of a number of factors in the adhesive, in the wood, in the nature of the surfaces, and in the application of the adhesive. It is designed to isolate the individual effects of the factors and to make possible the study of certain types of interactions which in the past have confounded many experiments.

One of the important areas of fruitless conjecture in wood gluing concerns the matter of how thick a glue line should be for maximum performance. The answer to this question has a bearing on the entire gluing operation because it presumably defines the quality of workmanship that is needed, and hence governs an item of cost. Use-instructions for wood adhesives, however, usually state that joints should be as close-fitting as possible for best results.

Knowledge of the tolerance of glues to varying thickness would therefore be a valuable element in the selection of the best glue for the job. Such knowledge would also lend emphasis to the importance of adhering to prescribed quality standards in the preparation of material for gluing. Concomitantly, the same procedures would be available for investigating and improving glues in gap-filling properties.

While thickness of the glue line is the usual focus of attention in considering gap-filling properties, pressure on the adhesive is an important factor. Since most woodworking glues shrink on curing, another factor must also be considered, i.e. whether the wood surfaces are able to adjust with the shrinking adhesive as in the case of veneer, or whether the distance between surfaces is inflexible as in dowel joints. The latter case is believed to be the most severe because of the stress that would be introduced normal to the glue line. Hence thickness, pressure, and flexibility of the joined members may be considered principle factors affecting the performance of an adhesive under gap-filling conditions.

The object of this paper is to describe a method which permits the manipulation of the above factors in a specimen. Representative data are given showing the trends that may be observed. It is believed that subsequent research will correlate these trends with performance in actual constructions.

A vast amount of test data is available on wood adhesives and their application. This is an indication of the importance attached to the testing and evaluation of wood adhesives and the paramount interest shown towards advancing knowledge in the art of wood gluing. As full and complete as this file may be, there exists a scarcity of information on the characteristics of adhesives when functioning in thick glue lines in glued-wood joints.

Several reasons are apparent for this lack of information. First, there appears to be no suitable method for controlling the factors under which an adhesive must function when serving in gap-filling conditions. Second, there seems to be no true gap-filling adhesive capable of meeting the ideal theoretical requirements. Third and last, there appears to be a lack of recognition that surface and dimensional irregularities do exist, which

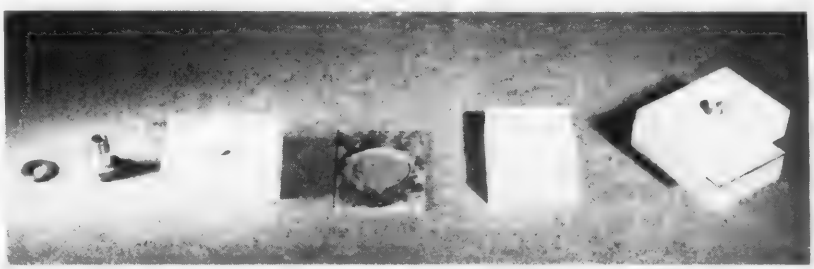


Figure 1.—Breakdown of specimen (l. to r.) rubber gasket, flange assembly, upper member, metal shim, lower member, assembled specimen.

[1] Submitted in the Graduate Division of the 1953 Wood and Wood Products Award Contest.

the adhesive must remedy in the final assembly.

Previous means (1) (2) (3) of investigating the effect of glue line thickness on strength, have been confined to two methods:

1. inserting shims between the members of the assembly (block shear blanks or sheets of veneer) to control glue line thickness.
2. measuring with a microscope and separating into thickness classes glue lines obtained under normal gluing procedures.

These methods have several disadvantages which affect the interpretation and reproductibility of the data. Chief among these drawbacks are:

1. the surface area of the shims receives the applied pressure, reducing the effective bonding pressure to zero, or, as in the second method, bonding pressure is an uncontrolled factor.
2. depending upon the flexibility of the members of the assembly, final glue line thickness and bond strength is a function of the amount of shrinkage occurring in the glue during curing and conditioning.

While these methods have been useful in drawing attention to the need for control in preparing wood surfaces for gluing, they do not appear to be sufficiently precise as a means for investigating adhesives themselves with respect to gap-filling properties.

In measuring a property of an adhesive, it is of prime importance that the test procedure reflect the controlled effects of the pertinent factors in both its composition and the manner in which it is used. Little knowledge about the adhesive is gained by supplying a gap in which it is to form a bond. This may of course indicate whether the adhesive does or does not form the desired bond under that particular condition. However no information is obtained on the causes for the showing, nor is there any assurance that the adhesive has the inherent ability to form a bond under slightly different conditions. The reason for the meager results is that the performance of an adhesive is being observed against a condition, but the condition is not well defined as to the factors it represents.

Consideration of the factors pertinent to the functioning of an adhesive under gap-filling conditions leads to the following partial list:

1. Shrinkage of the adhesive upon curing
2. Solvent loss of the adhesive
3. Solids content (resins, fillers and extenders)
4. Rate of cure
5. Degree of hardening
6. Compactness of the film
7. Cohesive strength of the cured adhesive
8. Moisture content of the wood (or absorbent power)
9. Porosity or specific gravity of the wood
10. Condition of the wood surface
11. Distance between the surfaces
12. Cohesive strength of the wood
13. Modulus of elasticity of wood and adhesive
14. Pressure received by the adhesive
15. Ability of the wood surfaces to follow the shrinking adhesive

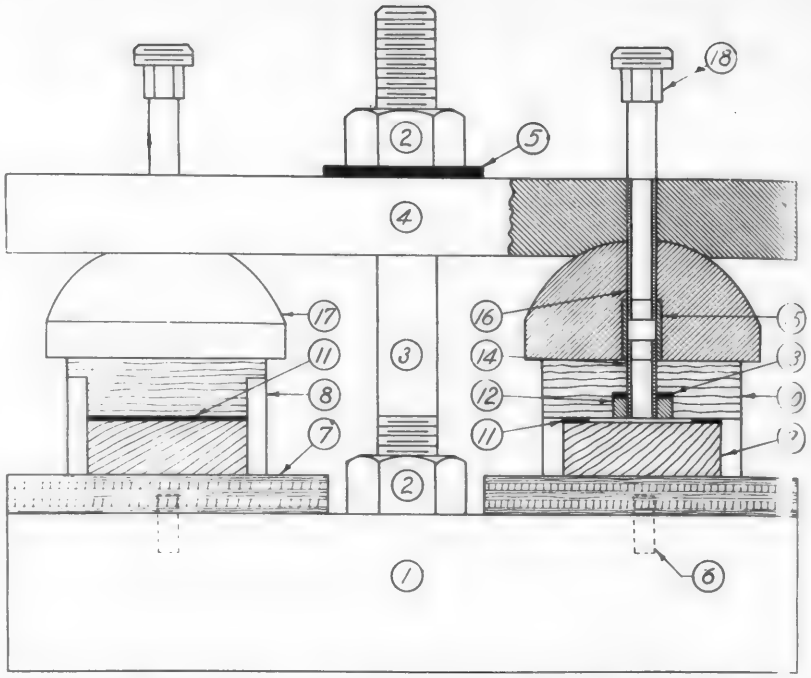


Figure 2.—Assembly jig. (4) cross-bar, (16, 18) air connection, (12) flange assembly, (11) metal shim, (13) rubber gasket, (17) bearing block, (8) positioning pin.

The problem in devising a suitable test method for observing whether an adhesive possesses gap-filling properties appears to reduce to a strength specimen in which three principle variants can be controlled at predetermined levels. These are (1) distance between the joined surfaces (2) rigidity of the joined members and (3) pressure received by the adhesive. It was believed that if these three variants could be manipulated in a strength specimen, the effects of the other variables might be observed. For example, the effect of shrinkage of the adhesive can be studied by varying the glue line thickness, at constant pressure, using rigid, restrained surfaces, and comparing the strengths observed at varying lengths of cure time. By introducing other controlled variables into the pressure-thickness-shrinkage system it is believed that subsequent experiments will show correlations which may point to means of improving the property of gap-filling.

The Test Method

As previously mentioned, a method and procedure that defines the ability of an adhesive to operate under gap-filling conditions requires positive control over glue line thickness, bonding pressure and the relative mobility or flexibility of the adherends. Adherend is henceforth used as a general term referring to the material being bonded.

Achieving control over glue line thickness and bonding pressure (distinct from pressure applied to the assembly) permits these two factors to function independently of each other. Control over the relative mobility of the adherends has the advantage of closely reproducing the conditions where the adherends are free to move or are restrained from adjusting to the shrinking adhesive as cure progresses.

The scope of this portion of the research is to describe a method that controls these factors. This has necessitated (1) a new approach to the application of bonding pressure in a test specimen; (2) a refinement of the method of inserting shims to control glue line thickness; (3) a provision for observing effects of mobility of the adherends; and finally (4) a modification of a test specimen to fulfill these requirements.

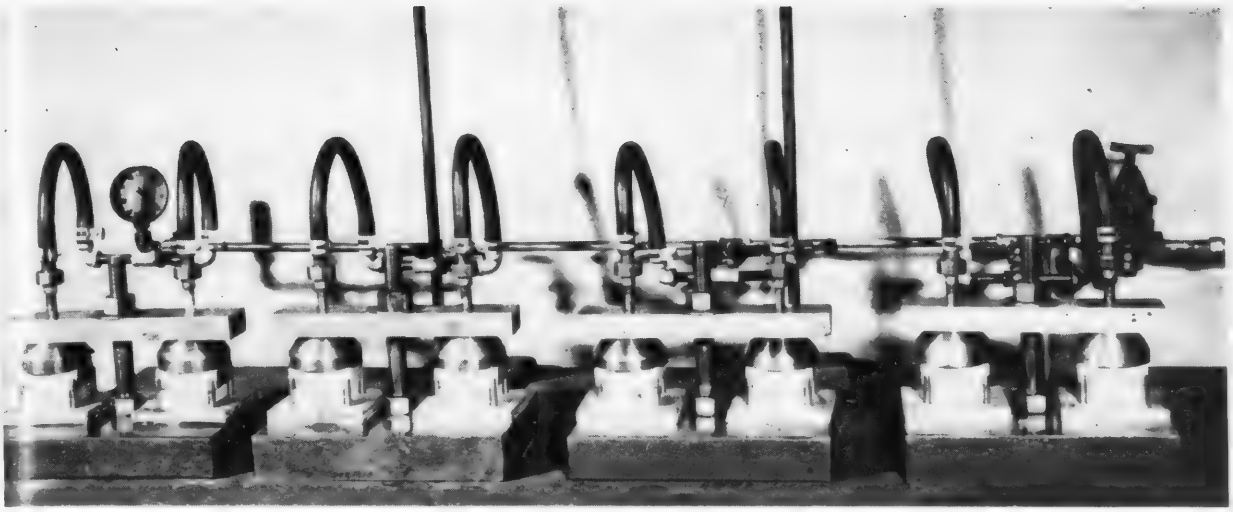


Figure 3.—General view of assembly jigs.

The functions of pressure in gluing have been identified by many investigators, and may be divided into four components; (1) to bring surfaces into alignment, (2) to compress high spots on surfaces, (3) to overcome friction in moving parts of press, and (4) to apply hydrostatic pressure on the adhesive. Perhaps the most important of these, from the standpoint of adhesive activity is the hydrostatic or fluid pressure. Fluid pressure is of fundamental importance because it (1) aids chemical adhesion by facilitating the close molecular proximity necessary for it to occur, (2) it forces the adhesive into the wood to promote mechanical adhesion, and (3) it serves to make the adhesive film more compact and hence stronger. It may be reasonably inferred that fluid pressure is the effective bonding pressure and it is this pressure that must be controlled in adhesive evaluation experiments. The other functions of pressure are more or less indeterminate in their effect on the adhesive. Absolute control over fluid or bonding pressure is possible with compressed air. As this approach is an application of Pascal's Law (4), pressure is distributed uniformly throughout the adhesive film and its full effectiveness may be realized. Furthermore, it eliminates a mechanical means for follow-up pressure. Of equal importance is that application of pressure in this manner permits a clamping component to function independently, thereby separating bonding from clamping pressure. Another advantage is that it remains as an effective method of duplicating with controlled variations the low pressures normally associated with the bonding of poor-fitting joints and gaps in laminated lumber.

In this method, pressure is divided into two components, one holding the surfaces together and the other acting directly upon the adhesive to promote those functions of penetration and solidification which adhesives normally need to form a strong bond. Thus it is possible to determine how much actual bonding pressure a particular adhesive requires, and this is not obscured by the other components of pressure.

Test Specimen: The test specimen is a modification of the cross-lap specimen currently being studied at the Department of Wood Technology of the University of Michigan and previously described by other investigations (5) (6) (7) (8). In this specimen two short blocks of wood are assembled at right angles forming a simple symmetrical cross and glued in a normal manner. The overlap provides bearing areas for the application of a testing force in direct tension.

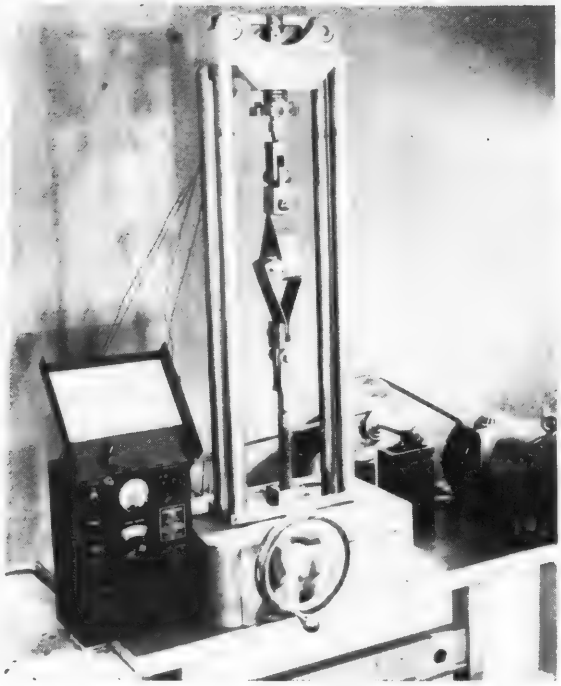
In modifying this specimen, Figure 1, the upper member is drilled with a $\frac{7}{16}$-inch hole through the center and counterbored ¾-inch to a depth of $\frac{5}{16}$-inch. Inserted in this counterboard hole is a flange and nipple through which compressed air is applied directly to the glue as bonding pressure. Between the members of the specimen is placed a metal shim of the same width and length as the wood blocks and a predetermined thickness to control glue line thickness. A circular area is removed from the center of this shim where, in assembly of the specimen, the glue line is formd. A circle $1\frac{7}{16}$-inch in diameter gives a bonding area of one square inch, allowing 0.4 square inch for the area of the flange. To prevent a bond between the members of the specimen and its metal components, the shim and flange assembly are dipped in hot paraffin. The specimens are set up for gluing, two to an assembly jig, Figure 2.

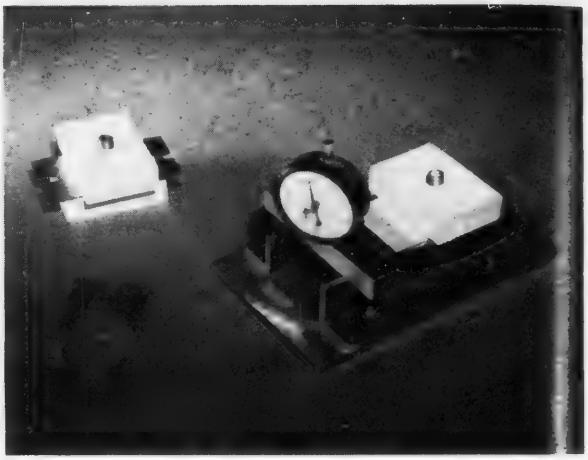
Application of Pressure: *A. Clamp pressure.* Pressure to hold the two members of a specimen together is brought to bear by means of a clamping arrangement as shown in Figure 3. This clamp holds the specimen in correct alignment, keeps the shim centered, and at the same time permits the air coupling to pass through the bearing blocks. The assembly jig consists of a base, locating pins, spherical bearing caps, cross-bar and center-post.

The cast iron jig base contains a ¾-inch center-post which is threaded on both ends and secured in the base by a lock nut. Locating pins position a specimen and shim on either side of the center post. The spherical bearing caps, which rest on the upper members of the specimens, are machined to provide a crown that fits into a concentric recess in the cross-bar. The mating of the bearing caps and cross-bar in this manner provides a uniform distribution of pressure on the shim ensuring an effective seal against the fluid pressure.

Clamping pressure is obtained by applying a force to the cross-bar. This is accomplished by a nut on the center-post. The force is transmitted through the bearing caps to the upper member of the specimen and hence, to the metal shim. Inasmuch as clamping pressure operates independently of fluid pressure, a quantitative measure of the former pressure is not essential. Only sufficient clamping pressure is required to seal the joint against escape of the adhesive.

B. Bonding pressure. Air pressure which serves as the fluid bonding pressure is led to the glue line through appropriate valves and nipples as shown. All specimens in a run (12 in number) are attached to a common header in which the air pressure is regulated by an air control valve.





↑ Figure 5.—(Right) Jig for measuring shrinkage of glue line in a specimen with shim removed. (Lower left) Split shim. (Upper right) Specimen with split shim in place.

←——— Figure 4.—Set-up for testing the specimen.

Thus all specimens receive identical pressure.

Glue Line Thickness: A method for evaluation of thick glue lines must take into consideration the ability of the adherends to adjust to the shrinkage of the adhesive while cure progresses. Two conditions of adherend adjustibility may be recognized, (1) where the members of the assembly are capable of deflecting sufficiently to accommodate to the shrinking adhesive, such as veneers in flat plywood or lumber core panels, (2) where the members of the assembly are restrained in adjusting to the shrinkage of the adhesive as is often the case in laminated structural members or various types of joints in furniture construction. It is logical to assume that internal shrinkage stresses will be present in the latter case which are more detrimental and therefore a greater loss in bond strength can be expected.

To duplicate these conditions two shim types were developed. For the first, a split shim was so designed that it could be removed from the joint. Removal can be accomplished soon after the adhesive gels, at which point it is felt that fluid pressure is no longer effective. Hence the two members of the specimen are free to move together as the adhesive shrinks. For the second condition, a one piece shim remains within the specimen until tested, permitting the same internal shrinkage stresses to operate in the test specimen as could be expected under normal gluing of restrained joints.

Research results presented in this paper deal only with the latter since it was considered that restrained conditions represent the severest test for evaluating gap-filling properties of adhesives.

Testing the Specimen: As mentioned previously the specimen is tested in direct tension by applying a controlled force to the bearing areas provided by the overlap of the two members of the specimen. This may be accomplished with a suitable pair of grips in any testing machine capable of a controlled rate of load.

An Evaluation Study

Scope: It has been assumed that loss in bond strength will occur in a restrained joint due to shrinkage of the adhesive as cure progresses. The following portion of this research was designed to reveal the variation in bond strength when curing time and glue line thickness are varied in a test specimen in which the members are not free to adjust to the shrinking adhesive. In addition, tests were conducted to determine the effects of pressure on an adhesive and to observe the bond-forming ability of five different assembly adhesives under six glue line thicknesses at a cure time of seven days.

Design of Experiment: To determine the variation in bond strength that results from shrinkage stresses, a urea-formaldehyde type adhesive (modified to improve gap-filling properties) was observed under several glue line thicknesses, several intervals of cure, and one bonding pressure. Glue line thickness was varied in six levels: .005, .010, .019, .029, .041, and .064 inch under a fluid bonding pressure of 10 pounds per square inch. Eight intervals of cure varied from 4 hours to 14 days. Two specimens of each combination of thickness and cure were prepared and tested, giving a total of 96 specimens.

To determine the effects of pressure on a urea-formaldehyde type adhesive, the six glue line thicknesses (.005 to .064 inch) were observed at five bonding pressures: 0, 5, 10, 25, and 50 pounds per square inch, at a cure time of 24 hours. Two specimens were prepared and tested for each combination of thickness and pressure, a total of 60 specimens.

To observe the bond forming ability of representative assembly adhesives under varying glue line thicknesses, five adhesives were selected: a urea-formaldehyde type, a casein, a liquid animal glue, a polyvinyl acetate resin, and a phenol-resorcinol resin. Six glue line thicknesses were observed (.005 to .064), under 10 pounds per square inch and a cure time of seven days. Two specimens were prepared and tested for each combination of adhesive and thickness, a total of 60 specimens.

Control of Specific Gravity: It is well accepted that density will influence the strength of a glue-wood bond. In an attempt to reduce a source of variation in the test results, specific gravity (0.66) of the hard maple up-minus 0.02 of the mean specific gravity (0.66 of the hard maple up-

ply from which the stock for the specimens was obtained. This was achieved by closely following the statistical methods described by Markwardt (8).

Control of Moisture Content: To eliminate internal stresses resulting from dimensional changes of the members of the specimen which in turn result from variation in moisture content, the assembly and gluing operation was carried out in a constant humidity room at an equilibrium moisture content of 8 per cent. After removal from the jigs, the specimens remained under these conditions until tested. All stock was pre-conditioned to 8 percent moisture content prior to machining.

Testing the Specimen: Testing was performed on a small tensile testing machine fitted with special grips, Figure 4. Load was applied at the rate of 2000 pounds per minute by means of a motor and pulley attachment. To increase the accuracy of the results, SR–4 strain gages were mounted on the dynamometer of the dial gauge normally associated with this type of equipment. With an SR–4 strain analyzer, bond strength was measured in micro-inches of deflection of the dynamometer to which the grips were attached. These values were then converted to pounds per square inch by a conversion factor obtained by calibrating the dynamometer. To ensure a uniformly distributed tensile load upon the specimen, double clevises were attached to the grips to permit them to adjust in response to stresses developed during breaking.

Discussion of Results: It is evident from Table I, that cure time has considerable influence on bond strength in the various glue line thicknesses, and that certain trends are exhibited in the behavior of the adhesive used in this portion of the study.

The trend of decreasing bond strength with increased glue line thickness during the first twelve hours of cure is significant. A reason for this can be advanced. It is recognized that room setting adhesives, such as the modified-urea-formaldehyde type used, cure as the result of chemical action. However, another factor enters into the rate of strength development, that is, solvent loss. This data indicates the substantial effect of solvent loss on rate of strength development as well as on the total strength achieved. It may be reasonably assumed that thinner glue lines are subject to the same rate of polymerization as the thicker ones. However, the thinner glue lines apparently experience a rapid loss of solvent. Thus, some cohesive strength in thin adhesive films is established in a shorter period of time and this development of cohesion is reflected in the measured strength of the bond. On the other hand, a thick glue line developes little or no bond strength during the same interval of cure time and remains a viscous mass with little or no cohesive strength.

Table I—EFFECT ON BOND STRENGTH OF CURE TIME AND SHIM THICKNESS FOR A MODIFIED UREA-FORMALDEHYDE TYPE ADHESIVE AT 10 POUNDS PER SQUARE INCH PRESSURE

Cure Time	Strength—pounds per square inch Shim Thickness					
	.005	.010	.019	.029	.041	.064
4 hours	455	104	10	10	0	0
8 hours	900	1250	800	490	215	80
12 hours	560	970	1410	1370	730	360
24 hours	735	715	1045	1120	1325	1250
48 hours	880	965	985	1350	1210	1370
96 hours	915	1060	930	1255	1290	1320
7 days	965	1005	1000	1250	1120	0
14 days	865	1105	1170	1120	0	0

Table II—EFFECT OF PRESSURE AND THICKNESS ON BOND STRENGTH FOR A MODIFIED UREA-FORMALDEHYDE TYPE ADHESIVE CURED FOR TWENTY-FOUR HOURS

Pressure (Pounds)	Strength in Pounds Per Square Inch Shim Thickness (Inches)						
	.005	.010	.019	.029	.041	.064	Aver.
0	885	1035	1120	1200	1390	1440	1175
5	830	1020	1050	1250	1310	1470	1150
10	735	715	1040	1120	1325	1250	1030
25	920	1200	1370	1320	1500	1260	1260
50	1080	875	1250	1345	1175	1235	1160

Table III—STRENGTH OF FIVE ASSEMBLY GLUES CURED FOR SEVEN DAYS UNDER VARYING GLUE LINE THICKNESSES

Adhesives	Strength in Pounds Per Square Inch Shim Thickness (Inches)					
	.005	.010	.019	.029	.041	.064
Modified Urea	965	1005	1000	1245	1120	0
Casein	645	1100	1220	1070	630	430
Animal	1080	1030	1200	1060	855	280
Polyvinyl	1180	1160	825	655	390	260
Resorcinol	1030	1160	1160	1030	135	0

It can also be noted that peak strength was reached for each glue line thickness at a different cure time. The peak tended to appear at a progressively later time with each increase in thickness. This further substantiates the belief that development of cohesive strength within the bond is not dependent solely upon chemical action but may also depend upon loss of the solvent.

After this peak has been reached the strength falls off, notably within the thicker glue lines. It is this fall-off in strength with time that governs the maximum thickness an adhesive can tolerate. Maximum strength alone is not therefore a reliable criterion of performance. The strength of the .064-inch glue line reduced to zero at the end of seven days, and at the end of fourteen days the .041-inch glue line also reached zero. It is conceivable that if time had been extended further, the other glue lines would show varying rates of strength loss proportionate with thickness until a thickness was reached that would be capable of maintaining strength indefinitely. This end-point could then be considered the maximum tolerable thickness for that particular glue.

A possible explanation for these end-points may be the effect of internal shrinkage stresses which arise as the result of contraction of the adhesive during cure. Since the joint is prevented from adjusting to these contracting forces by reason of the shim, a partial relieving of these stresses is not possible. Hence, they are manifested within the adhesive film as a strength loss. When the magnitude of these contracting forces exceeds the internal strength of the adhesive the specimen delaminates. This occurs more readily with the thicker glue lines since the effects of contraction within a glue line will be proportionate to its thickness.

The fact that the thicker glue lines exhibited a greater bond strength at cure times of twenty-four to ninety-six hours than the thin ones, indicates that this aspect of the situation requires considerable study. It appears to be contrary to the established thickness–strength rule that the thinnest glue line is the strongest. It has been suggested that the phenomena observed here may be a function of the plasticity of the adhesive at these various cure times. Inasmuch as the adhesive has not hardened completely and the retained solvents have a

strong plasticizing effect, the adhesive remains in a somewhat plastic condition. In this condition internal stresses are neutralized due to internal flow and, furthermore, a breaking force will be more uniformly distributed through the film. This results in a bond with a greater breaking strength. However, in view of the interaction of rate of solvent loss with thickness, it is difficult to arrive at definite reasons for the apparent anomaly at this stage in the investigation.

From the information contained in Table II, it can be seen that bonding pressure is not a critical factor with the adhesive used under the conditions of this study. A reason for this result may lie in the conditions of the experiment. It may be assumed that the bonding conditions used were extremely favorable to adhesion. As previously mentioned, the lumber used for these tests was pre-conditioned prior to machining and maintained under controlled conditions of humidity and temperature during assembly and curing. In addition, the stock was accurately planed before the specimens were cut to their final form.

Other adhesives may or may not react in a similar manner under the same or other conditions. It is apparent that bonding pressure needs to be more fully investigated under other controlled conditions if its true function in bonding is to be fully understood.

The five adhesives selected to observe their bond-forming ability are normally associated with assembly gluing, but find wide application in other phases of wood fabricating. The variation in bond-forming ability is to be expected because of the differences in their chemical and physical nature and the manner in which they attain strength.

It is to be noted that casein and animal glue show a marked drop-off in strength in the thicker glue lines. With an extended cure time these two glues can be expected to show further reductions in strength and ultimately delaminate above their critical glue line thickness.

The polyvinyl acetate adhesive exhibited its greatest strength in the thinnest glue lines, with a drop-off in strength throughout the thicker glue lines. This adhesive had a marked plasticity in the thicker glue lines, indicating incomplete hardening which explains the low strength values. Longer cure times are required to observe whether this adhesive will also reach an end-point in strength as did the other adhesives.

Although the casein, animal and polyvinyl adhesives appeared to react in a similar manner as regards drop-off in strength at the thicker glue lines, a distinction can be made. The casein and animal glues lost strength because of the onset of crazing. The loss in strength shown by the polyvinyl on the other hand, is due to incomplete cure. The results for polyvinyl must therefore be considered inconclusive.

The modified urea-formaldehyde adhesive and the phenol-resorcinol-formaldehyde adhesive which cure by chemical action reached an end-point in the thickest glue lines at the end of seven days. Extended cure times might conceivably cause continued reduction in strength of the resorcinol in other thicknesses similar to the reaction of the urea-formaldehyde adhesive at the end of fourteen days.

While the bonding pressure was held constant at 10 pounds per square inch in this study, it is conceivable that an increase in pressure may cause an increase in ultimate strength of the various glue lines except for the urea-formaldehyde type adhesive. It is doubtful, however, that increased pressure would affect their bond-retaining ability in the thicker glue lines, since this seems to be controlled mainly by the shrinkage properties of the adhesives.

Summary

The information obtained in this study applies especially to the conditions established and the adhesives used. A number of trends have developed which may be expected of many adhesives. The results also indicate the method may be effective in isolating the principal factors which control the performance of an adhesive under gap-filling conditions. It is recognized the method is unrealistic in a sense. However, it serves to bridge the gap between methods which merely measure the chemical and physical properties of adhesives and those which attempt to evaluate adhesives under normal gluing conditions. Subsequent research is necessary to determine the full capabilities of the method. An attempt is made towards this end in the remainder of the research of which a part has been reported here. The remaining research is concerned with the correlation of glue line shrinkage and bond strength, using two adhesives of differential shrinking capacities. Furthermore, these same two adhesives are used to make a comparison of the variation in bond strength where all factors are held constant except the relative mobility of the adherends in respect to the adhesive. To measure the amount of shrinkage that occurs once the shim has been removed from the joint, a measuring device (Figure 5), was designed. Preliminary investigations have indicated shrinkage may be measured to an accuracy of .0005-inch.

Hope is expressed here that the method and research presented will aid in augmenting our basic information on wood adhesives and their application.

References

1. Poletika, N. V., Effect of Glue Layer Thickness on Strength of Bonded Wood. Report No. WE-170-M-2, Curtiss Wright Corp., Research Lab., November, 1945.
2. Poletika, N. V., Effect of Glue Layer Thickness on Strength of Joints. Report No. WE-170-S-1, Curtiss Wright Corp., Research Lab., August, 1943.
3. Bruce, H. D. and Cockrell, R. A., Effect of Thickness of Glue Line on Strength and Durability of Glued-wood Joints, Forest Products Lab. Report No. R1616, Sept., 1946.
4. Weber, R. L., White, M. W., Manning, K V., College Technical Physics, New York and London, McGraw Hill Book Co., Inc., 1947, page 181.
5. Moser, F. and Humphrey, L. M., The Joining of Glass with Organics, Pittsburgh Plate Glass Co., Glass Division Research Laboratories, Creighton, Pa.
6. Truax, T. R., The Gluing of Wood, U. S. Department of Agriculture Bulletin No. 1500, U. S. Government Printing Office, 1934.
7. Kollman, T., Technologie des Holzes, Berlin, 1936, Page 596.
8. Rudkin, A. W., A Simple Method of Testing Glue Lines in Tension. Australian Council of Science and Industrial Research Journal, November, 1947.
9. Markwardt, L. J. and Wilson, T.R.C., 1935. Strength and Related Properties of Woods Grown in the United States. USDA Tech. Bulletin No. 479, Washington, U. S. Government Printing Office.

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Allowable Loads For Common Bolts At Various Angles to the Grain For Southern Yellow Pine*

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Purpose of report is to supply information essential to the proper design of bolted joints in timber construction, particularly as to whether currently used formulas give equally safe values through a complete range of angles to the grain from 0 to 90 degrees.

Introduction

THE HANKINSON FORMULA, as given in the "1951 Revision of the National Design Specifications for Stress Grade Lumber and Its Fastenings",[1] is currently used to calculate the allowable loads which may be transmitted through a bolted joint. The validity of this formula, as well as that of the Osgood Formula,[2] has been the subject of considerable controversy in timber design literature. (References 8, 9, and 10 in Bibliography).

This report presents the results of approximately 110 tests with an attempt to determine the accuracy of these formulas when applied to bolts bearing at various angles to the grain ranging from 0 to 90 degrees.

Previous work done on bolt bearing at various angles to grain has consisted mainly of tests performed with aircraft bolts and aircraft structural material, namely Sitka Spruce. In 1928 the U. S. Forest Products Laboratory concluded an extensive four-year program which considered these materials and published their results in Technical Note No. 296.[3] Bolt sizes ranged from 0.50 inches to 0.16 inches in diameter and angles of load to the grain of the wood were 0, 30, 45, 60, and 90 degrees. The results of the tests were in close agreement with corresponding values computed by the Hankinson Formula.

In the following year, 1929, the Forest Products Laboratory conducted a series of tests to investigate the bearing capacity of common bolts in structural timber. Tests were conducted with loads at angles to the grain of the wood at 0 degrees and 90 degrees, with no tests being made at intermediate angles. The results of the tests were published in Technical Report No. 332.[4]

In 1952, Raymond G. Pitz, an undergraduate student at the University of Wisconsin, submitted a thesis entitled, "Allowable Bolt Loads at Angles to the Grain in Douglas Fir."[5]

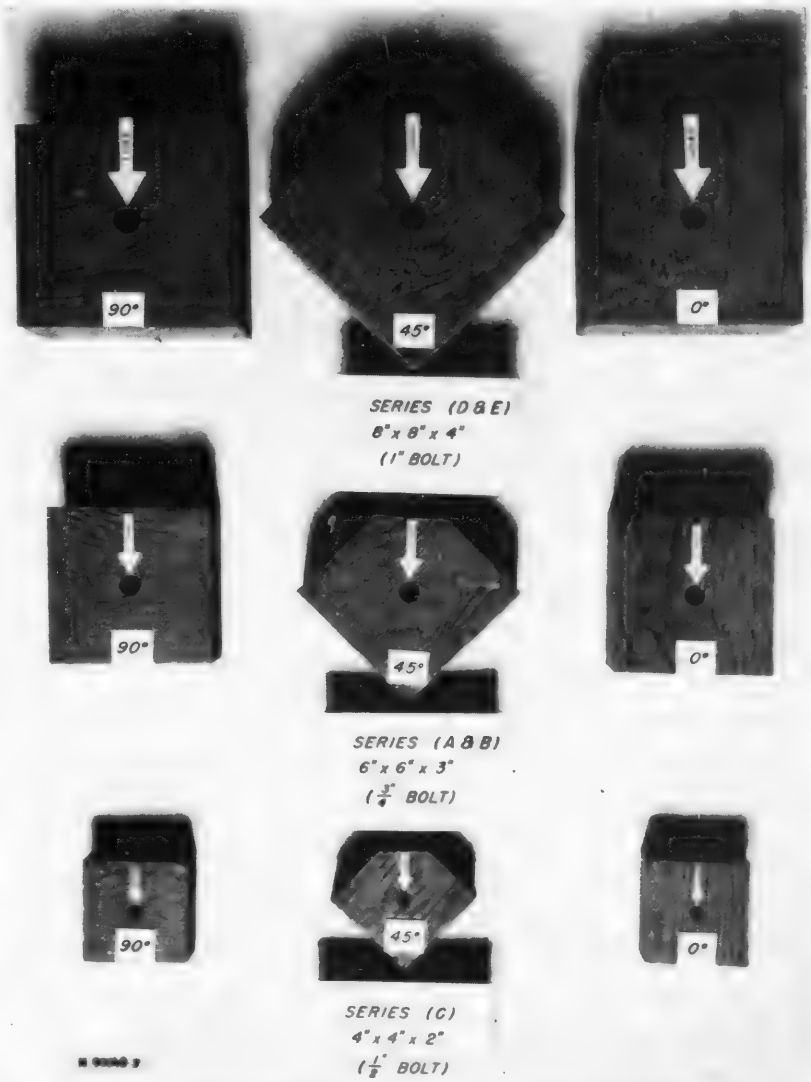

Figure 1.—Typical specimens showing sizes and direction of applied loads.

* Submitted for judging in the Undergraduate Division of the 1953 Wood and Wood Products Award Contest.

[1] National Lumber Manufactures Association: "National Design Specifications for Stress Grade Lumber and Its Fastenings," Washington, D. C., 1944, Revised 1951, p. 35.

[2] Osgood, Wm. R.: "Comparative Stress on Wood Surfaces Inclined to Grain," Engr. News Record, Vol. 100, No. 6, Feb. 9, 1928, pp. 243-44.

[3] Trayer, G. W.: "Bearing Strength of Wood Under Steel Aircraft Bolts and Washers and Other Factors Influencing Fitting Design," Nat. Advisory Com. Aeronaut. Technical Note 296, October, 1928.

[4] Trayer, G. W.: "Bearing Strength of Wood Under Bolts," U. S. Dept. of Agriculture, Techn. Bull. No. 332, October, 1932, 40 pp.

[5] Pitz, Raymond G.: "Allowable Bolt Loads at Angles to the Grain in Douglas Fir," an undergraduate thesis performed at the Forest Products Laboratory and submitted to the Civil Engineering Dept., University of Wisconsin, Madison, June, 1952.

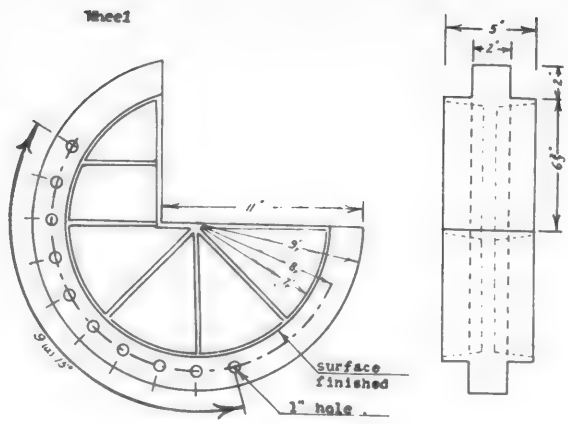

Figure 2.—Adjustable base for testing jig.

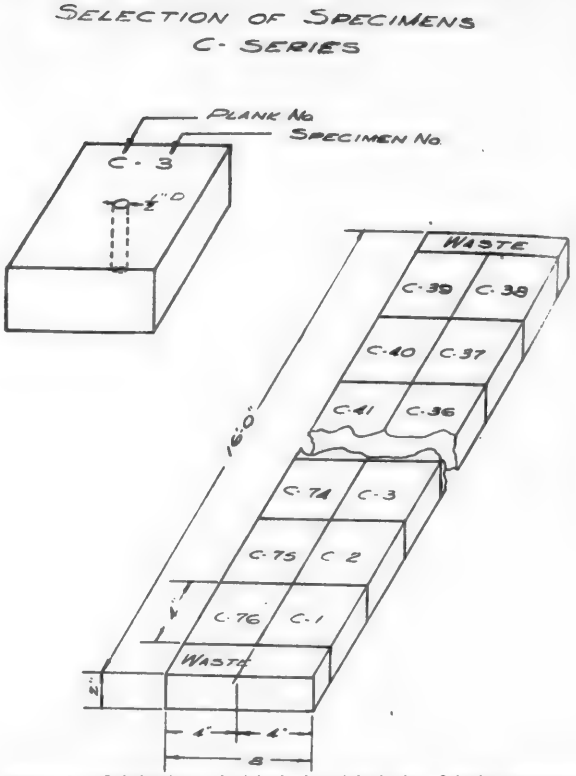

Figure 3.—Fabrication of 4-inch by 4-inch by 2-inch specimens.

Pitz selected Douglas fir as the material and used common machine bolts ½-inch, ¾-inch, and 1-inch in diameter, with loads applied from 0 degrees to 90 degrees, at 7½ degree increments, to the grain of the wood. His test results showed no conclusive agreement with either the Hankinson or Osgood Formulas but rather indicated that size of bolt used has an effect upon the load bearing capacities of Douglas fir. Since the series of tests on Douglas fir performed by Mr. Pitz were inconclusive as to a general equation for the ½-inch, ¾-inch, and 1-inch bolt sizes, an additional series of tests were run using Southern yellow pine to try to establish a consistent trend or relationship.

Selection and Preparation of Specimens

Material selected for the tests was Southern Yellow Pine because of its common use as structural material. Rough planks 2-inches by 8-inches by 16-feet were obtained. Care was taken to select the lumber so that the grain was straight throughout the entire length of the plank, and so that any defects which might affect the test results were eliminated. Minor tests to evaluate the quality of the test specimens show that the specific gravity was considerably higher than that of average southern yellow pine.

To obtain matched material for testing, each set of specimens was fabricated from one plank. A set consisted of 13 specimens which were to have loads applied at angles to the grain from 0 degrees to 90 degrees at 7½ degree increments. Figure 1 shows sizes of specimens and direction of applied load. A minimum of three specimens was tested at each angle.

The size of the specimens was determined not as a matter of choice but rather due to the limitations of the size of the testing jig which was available. The smaller bearing surface was 5-inches by 9-inches. (See Figure 2). This established the maximum specimen size that could be used. A constant $\frac{L}{D}$ ratio, where L = length of bearing area and D = diameter of bolt, was decided upon. Common machine bolts used were regular commercial bolts purchased from a building supply company in Madison. The size of the specimen was limited by the 9-inch length and 5-inch width of the test jig and a $\frac{L}{D}$ ratio chosen at 4 for length of bearing area. Thus 4-inch by 4-inch by 2-inch, 6-inch by 6-inch by 3-inch, and 8-inch by 8-inch by 4-inch specimen sizes were arrived at. The 4-inch by 4-inch by 2-inch specimen was tested with a ½-inch diameter bolt, the 6-inch by 6-inch by 3-inch with a ¾-inch diameter bolt, and the 8-inch by 8-inch by 4-inch with a 1-inch diameter bolt.

4-inch by 4-inch by 2-inch Specimens: These specimens were in the "C" series, as shown in Figure 3, ranging from numbers C—1 to C—76. A 16-foot length of 3-inch by 9-inch rough lumber, which had previously been selected, was planed to a 2-inch by 8 and ⅛-inch size, the ⅛-inch to allow for saw cut down the center. The board was then marked and cut into specimens.

6-inch by 6-inch by 3-inch Specimens: These specimens were in the "A" and "B" series, cut from two previously selected planks. They were fabricated in a manner similar to the "C" series specimens.

8-inch by 8-inch by 4-inch Specimens: These specimens were in the

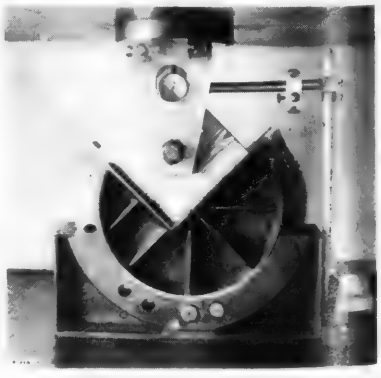

Figure 4.—Test equipment showing dial arrangement, adjustable base and loading plates.

"D" and "E" series, cut from two planks and fabricated in a manner similar to the specimens of the "A", "B", and "C" series.

After fabrication, specimens were conditioned to a uniform moisture content, 12½%, by placing them in a conditioning room where a relative humidity of 64% and a temperature of 75 degrees was constantly maintained. Weekly weight checks were made on a few randomly selected specimens in order to determine when they had reached proper conditioning.

After obtaining a 12½% moisture content, a hole was drilled vertically through the center of the larger face of the specimen corresponding to the nominal diameter of the bolt used. A 1-inch bit with a slow spiral was used for drilling the holes for the bolts having a 1-inch nominal diameter, and a ¾-inch and ½-inch machine with a fast spiral was used for drilling the holes for the bolts having a ¾-inch and ½-inch nominal diameter.[6]

After drilling, the specimens were returned to the moisture room where they remained until ready for testing

Testing Equipment and Testing Procedure

A four-screw, mechanical type, Tinius Olsen testing machine was used for loading the specimens. This machine has capacity limits of 2,500, 12,500, and 25,000 pounds and was found to be more than adequate for these tests.

The adjustable apparatus used for varying the angle of load application was positioned on the bed of the machine and a correction made for its weight. This piece of adjustable equipment consists of two main parts, namely, the wheel and the supporting base, as shown in Figures 2 and 4.

The wheel, actually 270 degrees of a circle, has ten 1-inch holes, spaced at 15 degrees, in its outer web. The supporting base has four 1-inch holes consisting of two sets of 2 which are spaced at 22 and ½ degrees apart with 15 degrees between the holes in each set. As the wheel is rotated in the frame, each set of adjacent holes in the wheel will be alternately aligned with those in the supporting base, at intervals of 7 and ½ degrees from 0 to 90 degrees. By rotating the specimens through 90 degrees it was not necessary to rotate the wheel past 45 degrees, since a setting of 7 and ½ would function equally well for a setting of 82 and ½ degrees.

Complete stability was obtained by inserting two pins into the aligning

[6] Goodell, H. R. and Phillips, R. S.: "Bolt Bearing of Wood and Modified Wood." U. S. Dept. of Agr., Forest Products Laboratory No. 1525. December, 1944.

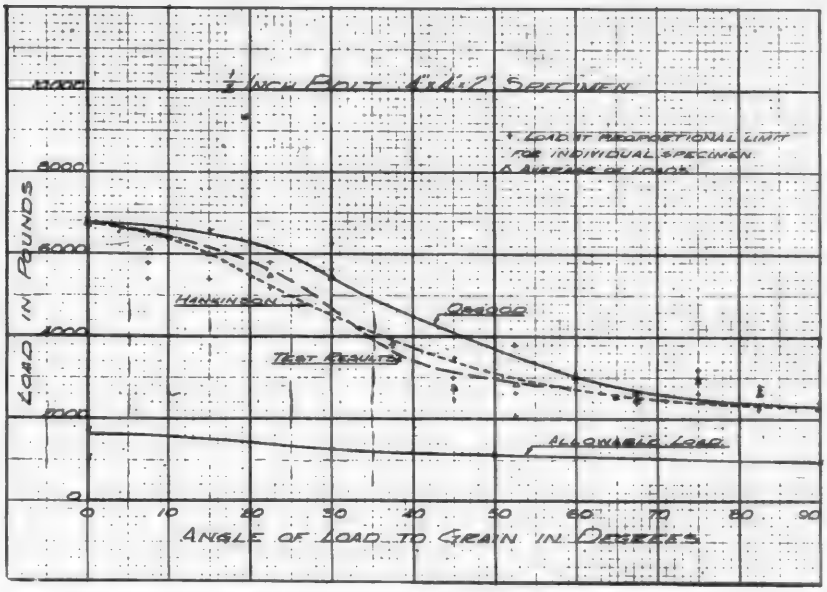
1 INCH BOLT 4"x4"x2" SPECIMEN
+ LOAD AT PROPORTIONAL LIMIT FOR INDIVIDUAL SPECIMEN
Δ AVERAGE OF LOADS
LOAD IN POUNDS
HANKINSON
TEST RESULTS
ALLOWABLE LOAD
ANGLE OF LOAD TO GRAIN IN DEGREES

Figure 5.—Curves for ½-inch bolt with load at various angles to the grain.

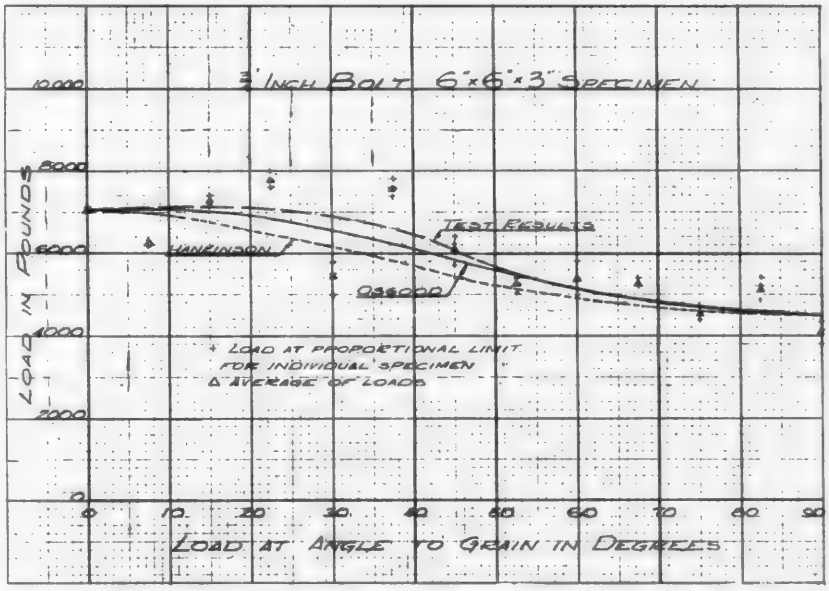
¾ INCH BOLT 6"x6"x3" SPECIMEN
TEST RESULTS
HANKINSON
+ LOAD AT PROPORTIONAL LIMIT FOR INDIVIDUAL SPECIMEN
Δ AVERAGE OF LOADS
LOAD IN POUNDS
LOAD AT ANGLE TO GRAIN IN DEGREES

Figure 6.—Curves for 3/4-inch bolt with load at various angles to the grain.

holes in the supporting base. All surfaces had been machined and hardened to insure a perfect contact and bearing surface.

Adjustable steel plates, 1-inch in thickness, were bolted to the head of the testing machine for the transmission of test loads. (See Figure 4). Each of these plates was fitted with a hardened steel bushing through which the test bolts were inserted. Because of the exact inner diameter of the bushings, it was frequently necessary to grind the bolts to corresponding nominal diameter to insure a proper fit. While testing the 4-inch and 6-inch specimens it was possible to bolt this arrangement directly to the head of the machine, therefore greatly facilitating the testing procedure. Because of the increased size of the 8-inch specimens, it was not possible to bolt the plates to the head; therefore, the load was transferred, by bearing, to the plates and then to the test bolts rather than directly through the plates.

Deformations were obtained by using a single dial gage having a least reading of 1/10,000-inch. This dial was supported at the end of an arm which projected from a supporting stand resting on the bed of the machine. (See Figure 4). When observation of the dial was difficult, the deformation was transferred by a one to one lever arm to a more accessible position of the dial.

A similar testing procedure was followed for all three specimen sizes. An initial correction was made for the

weight of the adjustable apparatus, specimen, and the recording equipment when it had been positioned on the bed of the testing machine. The speed of the machine, or the rate of load application, was set at .006 inches per minute. When the testing equipment had been properly arranged, the specimens were brought from the conditioning room in groups of two. This precaution was taken to eliminate the possibility of a specimen varying its moisture content while waiting to be tested. The specimen was then placed between the adjustable plates and loaded with an initial 200 pounds. The dial gage was then centered under the head of the machine and set to 0 deformation. (See Figure 4). As the load was applied, readings were taken at increments of 200 pounds until the rate of deformation became excessive. When it was reasonably certain that the specimen had passed its proportional limit, the load was removed and another specimen inserted. Due to the deformation of some bolts, a new bolt was used with each specimen. After the tested specimen had been inspected and marked, it was returned to the conditioning room.

In some cases, it was necessary to cut off a portion of the upper corner of the specimen in order to provide adequate space for the dial gage. It was felt that since only a small upper portion of the specimen had been removed, the test values would not be noticeably influenced. (See Figure 1).

Discussion

Figures 5, 6, and 7 show the relationship between the proportional limit loads and the angles to the grain at which the test loads were applied.

The Hankinson and Osgood Formulas, as stated below, were used as a basis for comparison and plotted on the same figures as the test results.

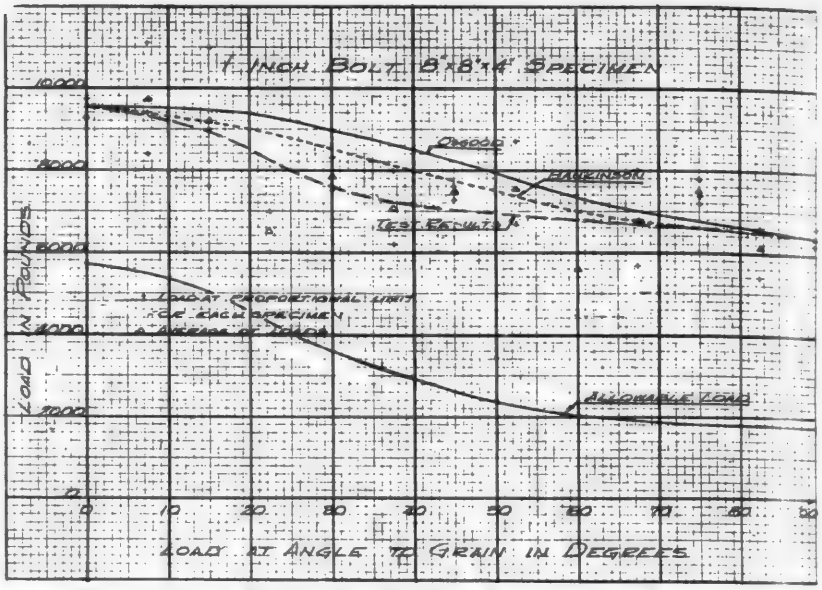

Figure 7.—Curves for 1-inch bolt with load at various angles to the grain.

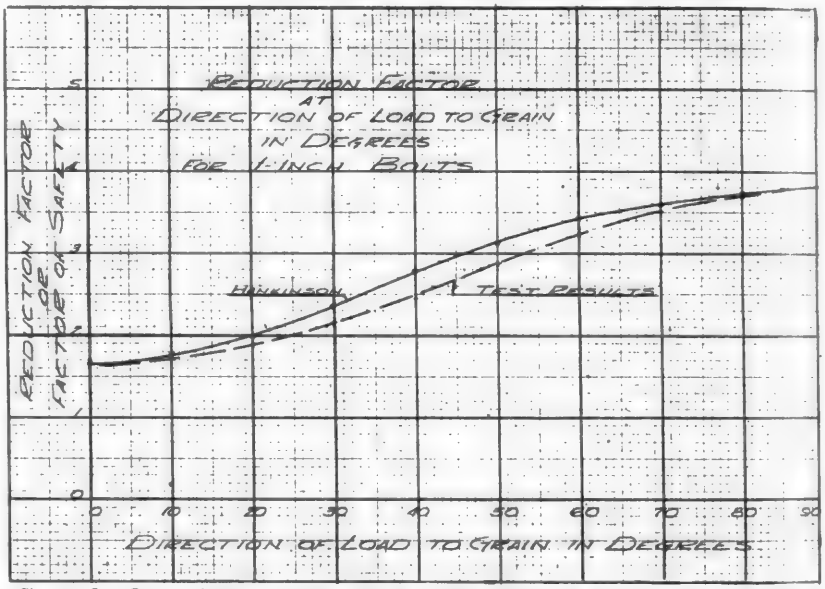
REDUCTION FACTOR AT DIRECTION OF LOAD TO GRAIN IN DEGREES FOR 1-INCH BOLTS
REDUCTION FACTOR OR FACTOR OF SAFETY
HANKINSON
TEST RESULTS
DIRECTION OF LOAD TO GRAIN IN DEGREES

Figure 8.—Curve showing relationship of safety factor of test results and that of the Hankinson formula.

$$\text{Hankinson Formula } n = \frac{pq}{p \sin^2\theta + q \cos^2\theta}$$

$$\text{Osgood Formula } n = \frac{pq}{q + (p-q)(\sin^2\theta + a\cos^2\theta)\sin^2\theta}$$

In the above formula:

- θ = the acute angle between the direction of load and the direction of the grain (See Figure 11a).
- p = the proportional limit load parallel to the grain
- q = the proportional limit load perpendicular to the grain
- n = the proportional limit load at θ to the grain
- a = a coefficient for the type of wood used, which for Southern Yellow Pine is given by Osgood as 0.35

It is evident from the tabulation of test results, that the wide variation of results for any given angle of load application may be attributed to something more than the non-uniformity of wood. It is felt that mechanical, specimen, and human inconsistencies merit enough consideration to be included in this report. The following is merely an enumeration of the possible sources of error and the authors do not attempt to make evaluations of, nor corrections for, any of them.

Eccentric loading may be considered among the principal mechanical errors. If the specimens are not cut squarely, or the hole through the specimen is not drilled exactly perpendicular to the plane of the axes, the specimen will bear on an edge rather than on a flat surface. This condition will result in a lower proportional limit because of the decrease in area of resisting the load.

Considerable bending of the ½-inch bolts was observed between the ranges of 0 degrees and 30 degrees as compared to virtually none in the ¾-inch and 1-inch bolts. Therefore, it is quite possible that the ½-inch bolts were reaching their proportional limit before or at the same time as the specimen. This would then limit the proportional limit of the specimen to the proportional limit of the

bolt. Because of the relative coincidence of the proportional limits of the bolts and the specimens, the proportional limit may be though of as that of the joint rather than that of either the bolt or the specimen.

An attempt was made to determine the proportional limit of the ½-inch bolts and through this determine a correction factor to apply to the joint which would give a true value for the wood. No satisfactory results were obtained because of the difficulty of loading the bolt exactly as it had been loaded in the actual test.

In actual design practice, bolt bending is not given consideration because the "p" and "q" values as given in the Hankinson Formula are actually the proportional limit load values of the joint rather than those of the wood.

As previously mentioned, these tests were carried out at an $\frac{L}{D}$ ratio of 4. This ratio was determined by the limitations of the testing equipment and other practical considerations, although the testing equipment could accommodate an $\frac{L}{D}$ ratio of 2 without additional alteration. A great advantage would be realized if this were done. If the same size specimens were used, the smallest bolts used would be 1-inch. Since no bending was observed in bolts larger than ¾-inch, bolt bending would be entirely eliminated, thereby producing more accurate values for the wood.

If the $\frac{L}{D}$ ratio were increased to 6, it would be necessary to change the size of the specimens to agree with the size of commercial bolts, since 5-inches is the greatest width that can be accommodated by the adjustable testing equipment. With reference to the proportional limit values of the wood, the test results would be virtually worthless since the largest bolt diameter used would be less than 1-inch, therefore causing excessive bolt bending in all specimens. Since bolt bending would be obvious in all specimens, it would be possible to get the proportional limit values of the joint which would be of as much practical value as that of either the bolt or the specimen.

The ever-present non-uniformity of the specimens themselves, such as knots, cracks, pitch pockets and specific gravities, must be given the usual consideration. However, for these tests only high quality material was used.

The direction of the grain as determined by the annual growth rings of the specimen in the parent timber

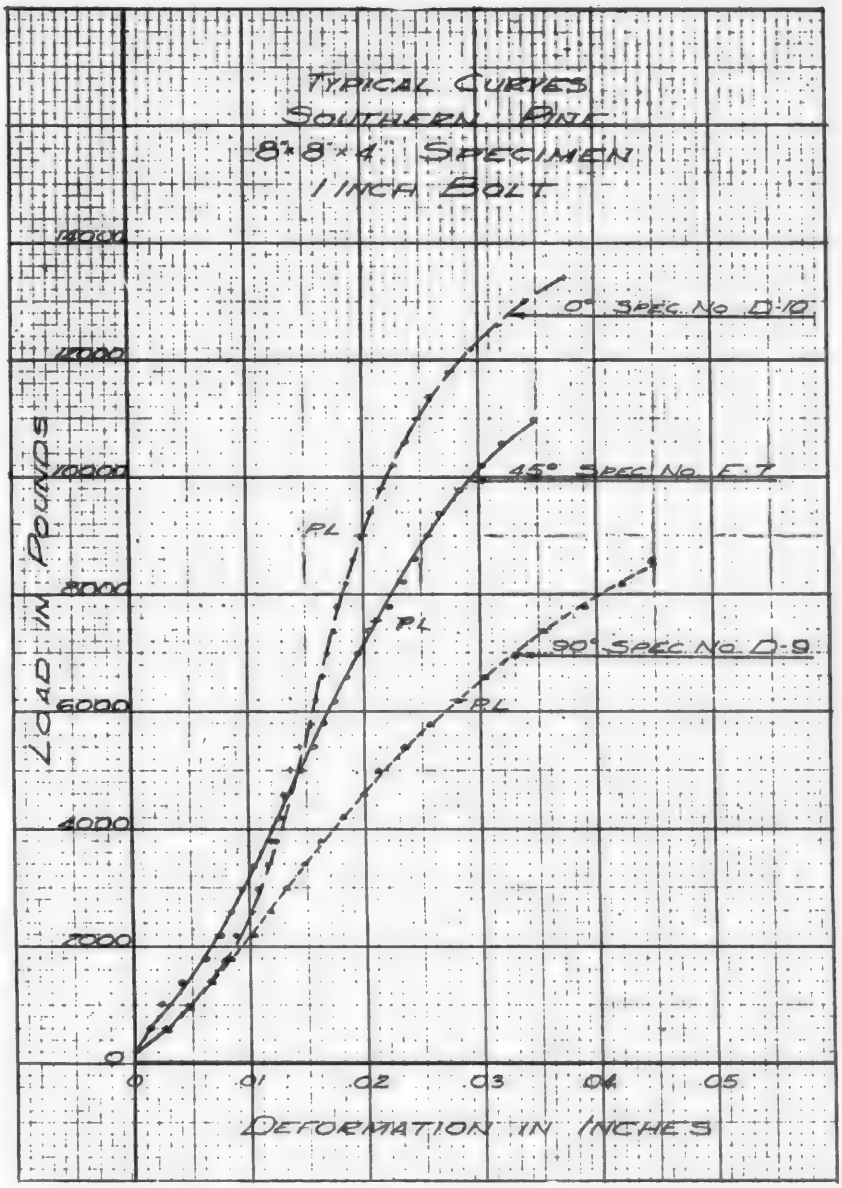

Figure 9.—Typical curves for 1-inch bolts.

requires more than passing interest. It was found that the proportional limit was noticeably higher in a specimen in which the growth rings were parallel to the bolt axis. Lower values for any given angle were obtained when the growth rings were perpendicular to the bolt axis. This confirms statements made in the U. S. Department of Agriculture Wood Handbook.[8]

The major human errors which may have contributed to any inaccuracy of the results may be attributed to plotting the test results and establishing the proportional limit. Although a large scale was used, it was difficult to accurately determine the proportional limit. In some cases, the unit deformation curve was very erratic, making the determination of the proportional limit, at best, a guess. An attempt was made to determine the relationship between the various proportional limits by finding the load at a given deformation. The results obtained by this method proved to be more variable than the original proportional limit estimation. Unless another method can be devised, the authors recommend that data such as this be plotted on an extremely large scale and the proportional limit determined directly from the curve. Greater accuracy can be obtained by plotting the data for any given specimen several times and averaging the proportional limits taken from these separate plots. Figure 9 shows load deflection curves for 8-inch by 8-inch specimen sizes.

[8] "U. S. Department of Agriculture Wood Handbook," prepared by the Forest Products Laboratory, Forest Research, Forest Service. Slightly revised, June, 1940, p. 56.

A curve for the allowable working loads specified by the "National Design Specifications for Stress Grade Lumber and Its Fastenings"[9] has been plotted for the 1-inch bolts at an $\frac{L}{D}$ ratio of 4. (See Figure 7). Note that P_{11} values are allowed a 25% increase for steel side plates. By comparing the values on the latter curve marked "test results", the actual safety factor or reduction factor can be determined when the proportional limit is used as a criterion. The theoretical safety or reduction factor which the present-day design specifications follow can be found by comparing the values on the allowable load curve with the corresponding values on the Hankinson curve. These comparisons have been made and are presented for 1-inch bolts in the form of a graph, as shown in Figure 8. A comparison of the actual safety factor to the theoretical safety factor will show the amount by which the margin of safety has been increased or reduced. Figure 8 shows that there is a variable reduction (approximately 5 to 11%) in the safety factor between 20 degrees and 60 degrees. The 1-inch bolt in the 8-inch by 8-inch by 4-inch specimen was chosen for this comparison because, due to the absence of bolt bending, relatively true values for the wood were obtained.

Conclusions

Figure 5 shows that the test results for the ½-inch bolt fall between Osgood and Hankinson in the 0 to 30 degree range and below Hankinson in the 30 to 90 degree range. This inconsistency may be attributed to the bolt bending which, as previously mentioned, was excessive between 0 and 30 degrees. The Osgood Formula is consistently higher than either the Hankinson Formula or the test results. Because of this, one could legitimately question the validity of Osgood's "a" value of 0.35. By increasing the value of "a", the three curves would be more nearly alike.

The test results obtained by Pitz[10] for the ½-inch bolt were lower than either Osgood or Hankinson between 0 and 45 degrees. Between 45 and 90 degrees Pitz was between Hankinson and Osgood.

Figure 6 shows that the test results for the ¾-inch bolts are above both Hankinson and Osgood, indicating that the test results more nearly approach the Osgood Formula. It is also evident that the 0.35 value for "a" is acceptable here, which is in direct conflict with the results of the ½-inch bolt test. In view of the inconsistent data, the authors recommend that these tests be rerun before any definite conclusions are drawn from this series. However, from the general trend of the available data, the authors feel confident that the Hankinson Formula is conservative and can be safely used in this series.

The test results obtained by Pitz for the ¾-inch bolts were higher than Osgood and Hankinson between 0 and 50 degrees, but favoring Osgood. Between 50 and 90 degrees Pitz was between Hankinson and Osgood.

Figure 7 shows that the test results for the 1-inch bolts differ noticeably from the general shape of the Hankinson and Osgood curves. In this instance, bolt bending was not a factor; therefore the proportional limit values may be considered as those of the wood only. The Osgood curve, as shown in Figure 7, is again considerably higher than the test results. This substantiates the possibility of an error in using "a" as 0.35. As in the ½-inch series, an increase of the "a" factor would lower the Osgood curve and approach the test results.

The test results obtained by Pitz for the 1-inch bolts were between Hankinson and Osgood in all ranges and favored Osgood.

The Hankinson curve for the 1-inch bolts has been evaluated on the basis of a safety or reduction factor rather than the proportional limit value of the wood. It was felt that since the original tests were carried out with plane bearing surfaces rather than bolt bearing, the safety factor analysis would be of more practical value. The safety factors, as determined by the National Design Specifications for Timber and Its Fastenings, are shown in Figure 8. The percentage differences between Hankinson and the test results varies from 5.1% at 20 degrees to a maximum of 10.9% at 40 degrees and back to 5.9% at 60 degrees. From a practical consideration, this range is critical in that a greater percentage of truss joint failures occur between 20 and 60 degrees than at values approaching 0 and 90 degrees. The authors recommend that the Hankinson values for "n" be decreased by 10% between the ranges of 20 and 60 degrees. Although the percent variation of the safety factor approaches a parabolic function, it does not warrant the additional calculation necessary.

The authors further recommend that additional tests be carried out on bolts exceeding 1-inch in diameter. There appears to be a "break even point" between the ¾-inch and 1-inch bolts beyond which the Hankinson Formula gives inaccurate results on the unsafe side. If further tests were performed, with emphasis on the 0 to 30 degree range and also at 90 degrees, the results would give a more accurate indication of the loading characteristics of these specimens.

[9] "National Design Specifications for Stress Grade Lumber and Its Fastenings," Table No. 12.

[10] Pitz.

Bibliography

1. National Lumber Manufacturers Association: "National Design Specifications for Stress Grade Lumber and Its Fastenings," Washington, D. C., 1944, Revised 1951, 66 pp.
2. Osgood, Wm. R.: "Comparative Stress on Wood Surfaces Inclined to Grain," Engr. News Record, Vol. 100, Feb. 9, 1928, pp. 243–44.
3. Trayer, G. W.: "Bearing Strength of Wood Under Steel Aircraft Bolts and Washers and Other Factors Influencing Fitting Design," Natl. Advisory Com. Aeronaut. Techn. Note 296, October 1928.
4. Trayer, G. W.: "Bearing Strength of Wood Under Bolts," Tech. Bull. No. 332, U. S. Dept. of Agriculture, Oct. 1932, 40 pp.
5. Pitz, R. G.: "Allowable Bolt Loads at Angles to the Grain in Douglas Fir," an undergraduate thesis performed at the Forest Products Laboratory and submitted to the Civil Engineering Dept., Univ. of Wisconsin, Madison, June 1952.
6. Goodell, H. R., and Phillips, R. S.: "Bolt Bearing Strength of Wood and Modified Wood," U. S. Dept. Agri. Forest Products Lab., No. 1532, December 1944.
7. U. S. Department of Agriculture Wood Handbook," prepared by the Forest Products Laboratory, Forest Research, Forest Service. Slightly revised, June 1940, p. 56.
8. Osgood, Wm. R.: "The Hankinson Formula," Engr. News Record, Vol. 135, No. 20, Nov. 15, 1945, p. 646.
9. Smith, F. C.: "Hankinson Formula Applications for Stresses at Timber Joints," Engr. News Record, Vol. 135, No. 2, July 12, 1945, p. 50.
10. Hogue, C. J.: "Hankinson Formula Best," Engr. News Record, Vol. 136, No. 25, June 19, 1946, p. 1006.

Veneer Drying Rates and Factors Affecting Them[1, 2]

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Describes tests made to determine the effects of veneer thickness and drying condition on the rate of drying, and proposes a veneer drying theory based on heat transfer.

THE DRYING OF VENEER has often been looked upon as so simple a process as to merit little detailed study. The speed of drying and the relative freedom from defects that characterize the drying of veneer in large industrial driers, as compared to lumber drying, have perhaps served to create an erroneous impression that there are no great problems involved in this process. Yet only a casual inquiry will bring out the fact that the current knowledge of veneer drying is based largely on trial and error methods and that there is little understanding of the fundamental principles involved in the process.

Veneer is usually dried in large drying ovens, sometimes over 100 feet long, through which the sheets move on a continuous belt or roller conveyor. Temperatures in the drier are usually above 212° F. and may be as high as 375° F. or more. In designing such a drier it would be extremely helpful for the design engineer to know something about the drying rates of the wood as it progresses through the machine, for he must make decisions about the control and proper application of heat, air circulation, and possibly humidity at various points in the drier. In practice, questions arise about the development of casehardening, honeycombing, and buckling stresses in veneer drying. Proper operation of the drier, involving adjustment of the time schedule to fit the temperature conditions—which in turn may vary during the day depending on steam pressures available to the drier—and to fit the needs of the veneer, that may vary from time to time in species, density, thickness, initial moisture content, and in other respects, is a complicated task.

Apart from these problems, little is known about the effects of the high drying temperatures on the properties of the dried material—its strength, its hygroscopicity, its gluing properties, its check-resistance, its paintability, and so forth. The study described here had to do chiefly with drying rates. It dealt only in a cursory way with the development of drying defects, and not at all with the properties of the wood dried under different schedules.

The Measurement of Drying Rates

Some typical drying rate curves, representative of the data obtained in drying almost 200 test specimens of yellow-poplar, sweetgum, and redwood heartwood, are shown in figure 1. These curves were developed on the basis of individual weighings, taken at frequent intervals during the drying of small specimens under closely controlled conditions of temperature, air circulation, and humidity.

It is obvious that the study of veneer drying rates and of the effects of various factors on these rates would be greatly facilitated if a simple method for numerically expressing the drying rate curves shown in figure 1 were available. The usual method of expressing drying rates by stating, for example, that 1/16-inch birch veneer can be dried in 10 minutes at a temperature of 250° F. or that 1/8-inch fir heartwood dries in 10 minutes at a temperature of 350° F., does not lend itself to mathematical treatment for it fails to take into account possible variations in initial and final moisture content, the effect of external factors other than temperature, and variability in the drying material itself.

Lumber Drying Rates: An adequate method of measuring and expressing drying rates of lumber is afforded by use of the so-called diffusion-coefficient or "k-value" (6) (8).[4] The calculations leading to the development of this coefficient are based on the assumption that the diffusion of water through the wood to the surface, where it can evaporate freely to the air stream, is the limiting factor that determines the rate of drying at any instant during the cycle.

[4] Numbers in parentheses refer to literature cited at the end of this paper.

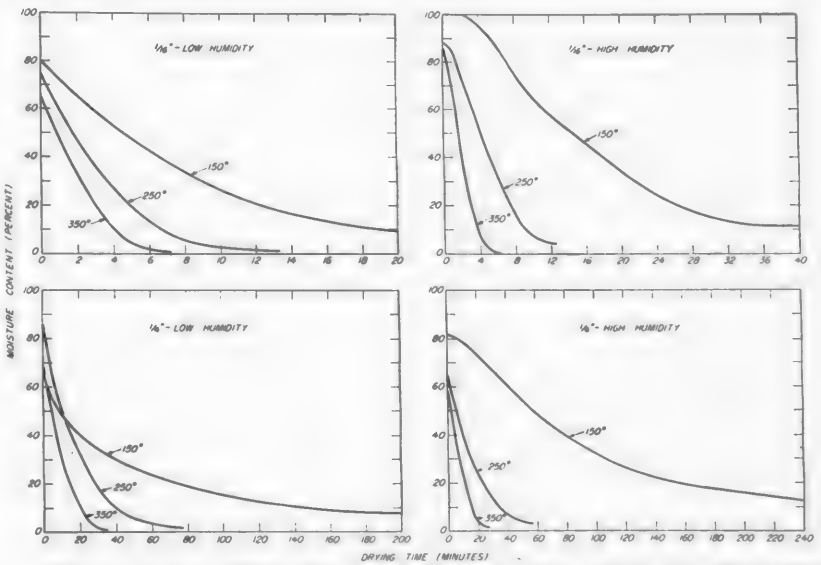

Figure 1.—Representative drying curves (moisture content vs. time) for yellow-poplar heartwood specimens, 1/16- and 1/4-inch thick, from log No. 1, dried at an air velocity of 600 feet per minute and at indicated temperature and absolute humidity conditions.

[1] This subject was presented by the author to the Forest Products Research Society at a meeting of the Central States Section at Louisville, Ky., on October 2, 1952, and to the Upper Mississippi Valley Section at Wausau, Wis., on December 9, 1952. The paper is based on work done at the Forest Products Laboratory and submitted to the Graduate School of Yale University as a dissertation for the degree of Doctor of Philosophy. The detailed report of this study is now in press and will be published under the title "Drying Rates of Thin Sections of Wood at High Temperatures," Bulletin No. 59, Yale University, School of Forestry, New Haven, Conn.

[2] A contributed paper.

[3] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

Tests on ¼-inch yellow-poplar heartwood veneer, dried at temperatures of 150°, 250°, and 350° F., at air velocities of 200, 600, and 1,000 feet per minute, and at two widely different humidities indicated that the conventional method of measuring drying rates with the aid of the "k-value," as in the case of lumber drying, can be used for this material. The "k-values" obtained in these tests agree well with coefficients calculated on the basis of diffusion as affected by capillary structure considerations (7).

Curve A, figure 2, shows the typical curve for the drying of ¼-inch material, when plotting drying rates over elapsed time during the drying cycle. This curve, normally a parabola, is similar to the curve representing lumber drying rates. Its shape is generally explained on the basis of diffusion phenomena (8).

Veneer Drying Rates Based on Heat Transfer: A different type of curve was found to represent the drying rates of specimens ⅛-, $\frac{1}{16}$-, and 1/32-inch thick. This type of curve, shown in B1 and B2, figure 2, is characterized by a sloping straight line over all or much of the drying cycle, when drying rates are plotted over drying times. Similar curves have been observed by others in veneer drying tests (5) and in the drying of paper (3). In these materials, therefore, the diffusion coefficient or "k-value" is of no use in measuring drying rates. Other investigators (1) and (4) also have not used the diffusion explanation in their studies of veneer drying rates.

Heat is required to evaporate water, and if there is no retarding influence such as a slow rate of diffusion through the wood to the point where evaporation takes place, then the amount and rate of evaporation should be proportional to the amount and rate of heat transferred from the surrounding media to the drying specimen.

Temperature data obtained during the drying cycle formed the basis for the calculations of heat transfer. Curves showing the temperature conditions during drying are shown in figure 3. These curves were based on temperature measurements at the surfaces and at midthicknesses of the test specimens during drying. All curves showed a rapid temperature rise early during the drying cycle, then a slowing up of the temperature rise as it approached the wet bulb temperature of the atmosphere (or 212° F. when the dry bulb temperature was above 212° F.), and finally a second more rapid rise and a gradual approach to the temperature of the drying atmosphere.

Figure 3 also shows, on the upper scale, the moisture content during the drying cycle. In most cases the point at which the second rapid rise in temperature began coincided approximately with the point at which the average moisture content dropped to the fiber saturation point, or between 25 and 30 percent.

Temperature curves for ¼-inch veneer indicated that a measurable temperature difference between surface and interior existed throughout the drying cycle. Such a temperature difference implies also a difference in water vapor pressures between surface and interior and hence also a difference in moisture content. Throughout the drying cycle of ¼-inch material, therefore, a temperature gradient, from a high temperature at the surface to a lower temperature inside, and a moisture content gradient, from high inside to low at the surface is evident. Temperature curves also showed that this condition existed in ⅛-inch veneer dried at the 150° F. temperature.

In the ⅛-inch veneer dried at 250° and 350° F., the temperature gradient was observable only in the first stage of drying, approximately before the temperature rose above 212° F. and the average moisture content dropped below the fiber saturation point. Beyond this point there was no observable temperature gradient, hence also no moisture content gradient. Diffusion of moisture or of heat through the thickness of the piece is therefore not a limiting factor in this range, and the rate of heat transfer from the external environment to the drying specimen may be assumed to control the rate of drying. The classification of specimens into two types, based on the mechanism that controls their drying, corresponds to differences in drying rate curves as illustrated in figure 2 by A on the one hand and by B1 and B2 on the other. For the common thicknesses of veneer, therefore, up to ⅛-inch thick and possibly thicker, any method devised for measuring and estimating drying rates ought to be based primarily on heat transfer rather than on diffusion data.

Characteristics of Veneer Drying Rate Curves: Figure 4 will be helpful in illustrating the relationship between the total amount of heat transferred to the specimen and the vaporization of water. Whereas the curves themselves, as drawn, indicate *rates* of heat consumption, the areas beneath them indicate total *quantities* of heat used. By far the largest part of the heat transferred is used to evaporate water, as is indicated by the lower curve. The area between the two curves indicates the quantity of heat not available for evaporating water, but used to heat the wood and the water in it. The relationship between the "heat of vaporization" curve shown in figure 4 and the drying rate curves, such as are presented in figure 2, curve B1, is a direct one. Since 539 calories of heat are required to evaporate one gram of water, the rate of drying, in grams per minute, is easily converted to heat of vaporization (in calories)

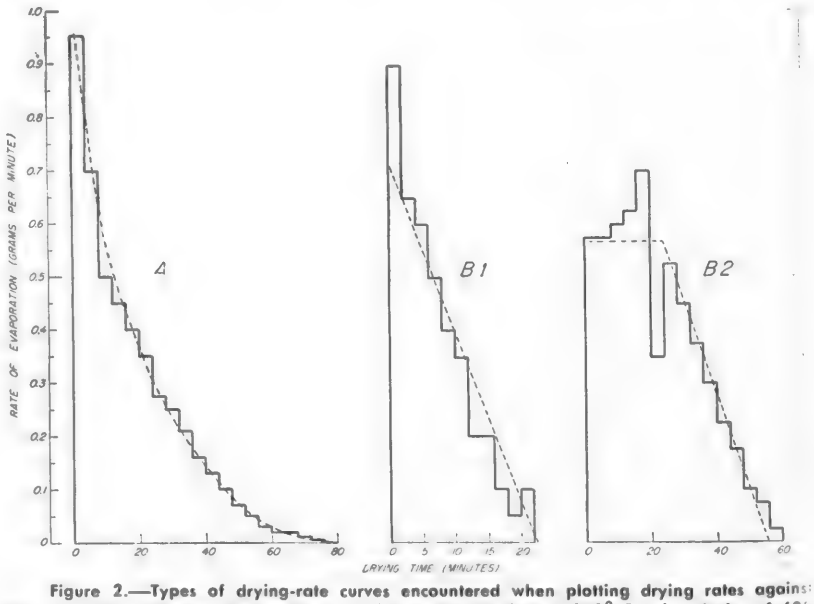

Figure 2.—Types of drying-rate curves encountered when plotting drying rates against time. A: From yellow-poplar log No. 1, ¼-inch thick, dried at 250° F., air velocity of 600 feet per minute, low absolute humidity; B1: From yellow-poplar log No. 1, ⅛-inch thick dried at 350° F., velocity of 600 feet per minute, high absolute humidity; B2: From yellow-poplar log No. 2, ⅛-inch thick, dried at 250° F., velocity of 600 feet per minute, high absolute humidity.

consumed per minute by multiplying the former by 539. A consideration of the interactions of a number of factors that affected the rate of heat transfer explained the typically straight-line relationship illustrated in figure 4. These factors, all of which were found to be constantly changing during the drying cycle, were the temperature and moisture content of the specimen, the overall specific heat of the wood and the water in it, and the rate of evaporation of water from the specimen.

The mathematical expression of the sloping dotted line, B1, in figure 2 is simple. The line intercepts the vertical axis at a value of 0.72 grams per minute. It intercepts the horizontal axis at about 22½ minutes. The slope of this line, expressed by the symbol "s", is therefore $0.72 \div 22\frac{1}{2}$, or 0.032. This means that the rate of evaporation per minute is decreasing on the average by 0.032 grams per minute. This value of "s" applies to a drying specimen of the size used in these tests, 3 by 6 inches. Converting to a specimen of unit size having a surface area of one square foot (i.e., specimen size 6 by 12 inches) yields the more useful term "S" which may be used in applying the method to commercial drying.

The S-value may be used as an estimate of drying time of veneer, for $\sqrt{S}$ is inversely proportional to drying time. If one veneer having an S-value of 1 dries in 10 minutes, then another having an S-value of 4 would dry $\frac{1}{\sqrt{4}}$ or one-half as fast, or in 5 minutes. This rule holds provided initial and final moisture contents are the same in both specimens.

When specimens varying greatly in initial moisture content, but otherwise identical, are dried under similar conditions the S-value is not necessarily different even though the total drying time may differ. Comparisons were made of yellow-poplar specimens from two different logs. The logs did not differ greatly in density but were greatly different in moisture content. Specimens from one had a moisture content of about 150 percent, while those from the other had about 75 percent moisture. A comparison of drying-rate curves for two such specimens of yellow-poplar veneer, varying greatly in initial moisture content, is shown in figure 5. The dotted lines for the two specimens, expressing average drying rates through the drying cycle, are approximately parallel and hence the "S-values" for the two specimens are the same. A statistical analysis of S-values established the validity of the conclusion that the great difference in initial moisture content did not affect the slope of the drying-rate line.

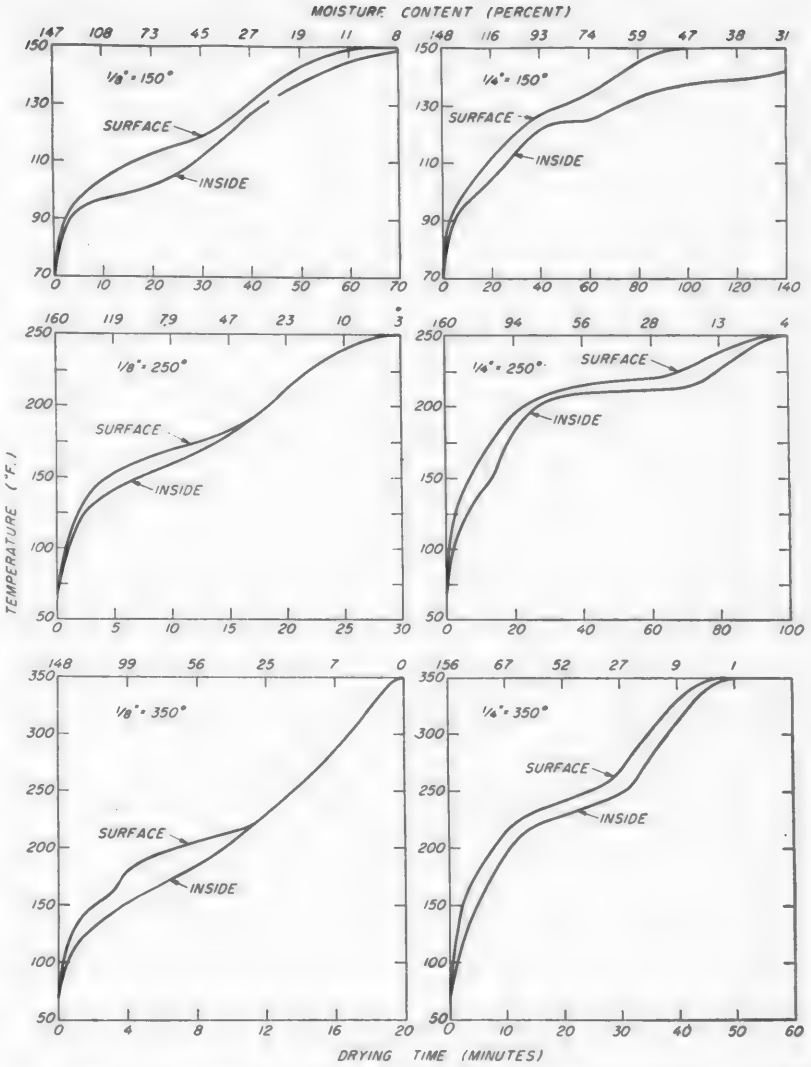

Figure 3.—Temperatures at the surface and inside specimens, and average moisture contents, during drying. Specimens were ⅛-inch and ¼-inch thick, from yellow-poplar log No. 2, and were dried at low absolute humidity, 600 feet per minute air velocity, and at the indicated temperature.

There was only one general exception to this conclusion. This exception is typified by the specimen illustrated in B2, figure 2. As pointed out previously, some yellow-poplar specimens displayed a distinct irregular or "constant-rate" drying period before the typical falling-rate period began. These specimens were all of the group that had a high initial moisture content of about 150 percent, and even then the phenomenon was pronounced only when the absolute humidity was high. Because of this high humidity, evaporation from the surface of the specimen could not begin until its temperature had reached the dewpoint temperature of the atmosphere, which in this case was 202° F. The very high water content of specimens from the wet log significantly retarded the warming up of these specimens. The delay in coming to the dewpoint temperature over the entire surface of the specimen explains why the typical falling-rate period did not begin almost at once. The phenomenon of course is apparent in all specimens, but was significantly so only under this particular combination of very high initial moisture content and very high humidity. Whether this particular condition is common in veneer driers is not known. If so, it can probably be controlled, when it occurs, by controlling the ventilation in the drier. For most of the specimens represented in this study, a "constant-rate period" at the start can be overlooked, and calculations can be based on the assumption that the "S-value" applies throughout the cycle.

Further analyses of test data were made to determine the effects of other factors, namely drying temperature, air velocity over the specimen, at-

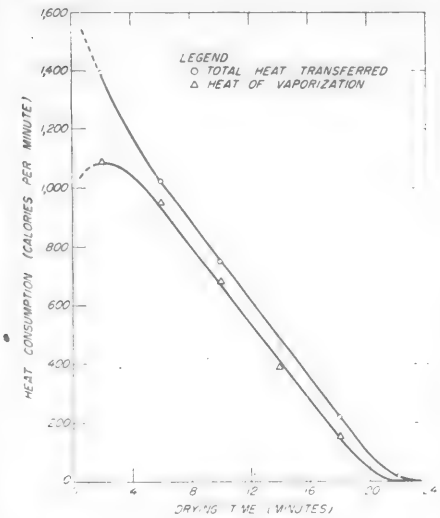

Figure 4.—Curves showing total heat transfer and heat consumed in evaporating water during the drying of a ⅛-inch yellow-poplar specimen from log No. 2, at an air velocity of 600 feet per minute, low absolute humidity, and a temperature of 350° F.

mospheric humidity, and thickness of the veneer. The drying rate, as expressed by "S-values" varied directly with temperature and air velocity, and indirectly with veneer thickness. The effect of humidity was more complicated. Specimens dried at a temperature of 150° F. showed a very significant effect of humidity, the rate varying inversely with humidity. At 250° and 350° F., humidity had no significant effect on the drying rate at all, except when combined with a very high initial moisture content of the wood, as explained above. The effect of humidity on S-values is apparently significant only when the drying temperature is below the boiling point of water, 212° F. The relationship is indicated in figure 6.

S-values for Yellow-poplar

In industrial veneer drying temperatures used in mechanical driers are usually over 212° F. The particular condition of high moisture content and very high humidity in the drier, that causes a significant "constant-rate" drying period and makes the S-value inapplicable over the entire drying cycle, probably does not, or need not, occur in a mechanical drier with adequate provision for ventilation. Except for these limitations, therefore, the S-value can be used to estimate drying rates of thin veneers under any given combination of factors. For the yellow-poplar specimens used in these tests, an estimating equation was derived by a least-squares calculation, as follows:

$$\text{Log } S = 2.98\,(\log T) + 0.78\,(\log V) - 1.34\,(\log D) - 11.34$$

where

T = drying temperature, °F.
V = air velocity, ft./min.
D = veneer thickness, in.

S-values obtained by use of this equation, for three thicknesses of yellow-poplar veneer dried at an air velocity of 600 feet per minute (probably a fair average for commercial driers) over a wide range of temperatures, are shown by the solid lines in figure 7.

Check tests on the heartwood of two other species of wood, sweet-gum and redwood, indicated that the method of expressing drying rates in terms of the S-value was also applicable to those species. The number of tests performed on these species was not great enough to justify a detailed mathematical analysis, but the S-values obtained for redwood specimens, as indicated by the dotted lines in figure 7, were not consistently higher or lower than those for yellow-poplar. The sweetgum values, on the other hand, were slightly but consistently lower than those for yellow-poplar, indicating that sweetgum heartwood drying rates may be significantly lower than those for the other two species tested.

How to Use the S-value: The information provided by the S-value and the drying rate data that it represents may be of use in connection with designing or modifying veneer driers to improve their efficiency. The value offers a convenient means for comparing drying rates of various species, thicknesses, or types of veneer. Of greatest interest to the practical man, however, is its use in connection with operating his veneer drier to obtain uniformly dry veneer. In general, the attainment of uniform moisture content in the dry veneer is attempted by controlling the only readily controllable factor, the time in the drier.

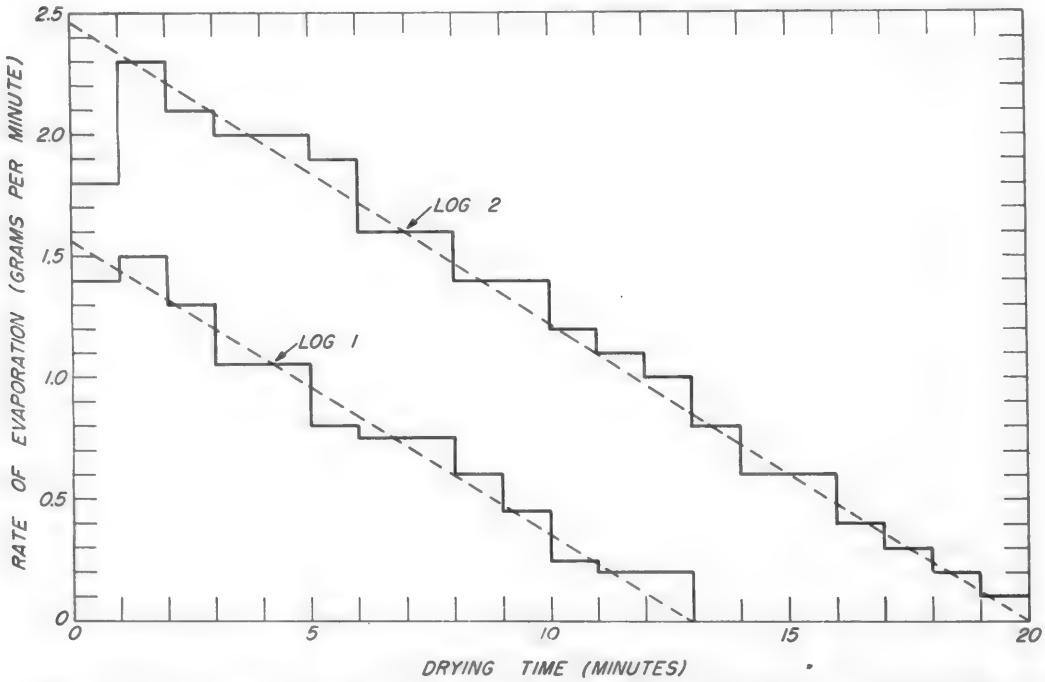

Figure 5.—Comparison of drying rates of yellow-poplar specimens having high (log No. 2, 148.5 percent) and low (log No. 1, 76.2 percent) initial moisture contents. Specimens were ⅛-inch thick and were dried at low absolute humidity, with an air velocity of 600 feet per minute and a temperature of 350° F.

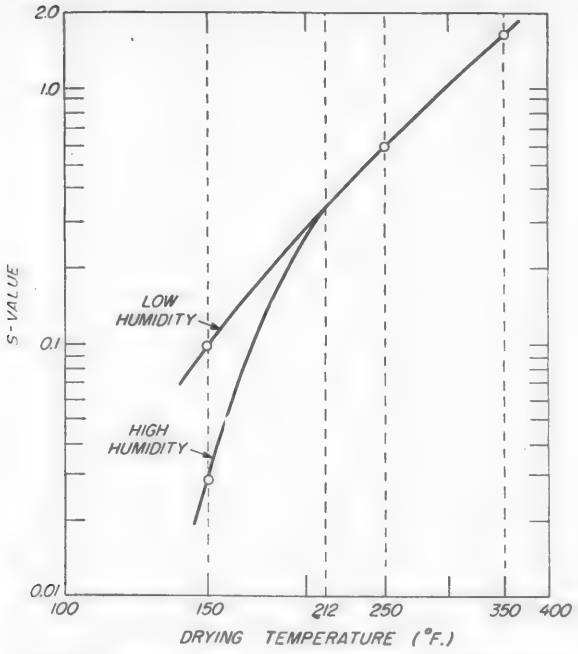

Figure 6.—Plot of S-values for log No. 1 based on averages of 1/32-, 1/16-, and 1/8-inch thicknesses, 200, 600, and 1,000 foot air velocities, and at 250° and 350° F. for both absolute humidities, illustrating the interaction of temperature and humidity and the curvilinear temperature effect at the lower temperatures.

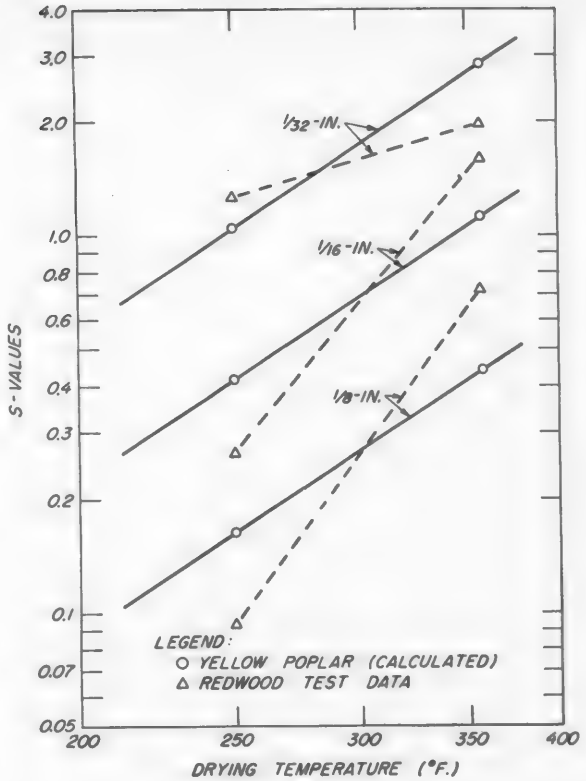

Figure 7.—Comparison of S-values obtained in drying tests of redwood specimens with values for yellow-poplar obtained by use of the estimating equation at an air velocity of 600 feet per minute.

This adjustment unfortunately must often be made by guesswork. Yet after accumulation of a few empirical data the method described here can be used to determine accurate and correct adjustments of time schedules, taking into account changes in species, veneer thickness, drier temperature, initial moisture content of the veneer, and final moisture content desired. The method is best illustrated by an example.

Let us assume that a piece of Douglas-fir heartwood veneer, 1/8 inch thick and 6 by 12 inches in size when green, is dried to a moisture content of about 3 percent. When green, the piece weighed 81.8 grams; after 9 minutes it emerged from the drier with a weight of 63.8 grams. Subsequently it was ovendried and weighed 62.0 grams. In order that a value for "S" may be calculated, it is necessary to know how long the veneer would have to be in the drier to come to the ovendry weight of 62 grams. The calculation of this apparently simple value requires the use of calculus. However, the necessary steps having been made, a relatively simple equation evolves that applies to the drying of veneer at temperatures above 212° F.

$$T = \frac{2Wt + \sqrt{(2Wt)^2 - 4(W-w)(Wt^2)}}{2(W-w)}$$

where

T = time theoretically required to dry to 0 percent moisture content, minutes

$\overline{W}$ = weight of water in the green specimen, grams

w = weight of water remaining at the end of the actual drying cycle, grams

t = actual drying cycle or time in drier, minutes.

For the specimen mentioned above,

W = 81.8 — 62 = 19.8 grams

w = 63.8 — 62 = 1.8 grams

t = 9 minutes

From the solution of the equation, we find that T or the time that would theoretically be required to bring the veneer to 0 moisture content in the drier would be 12.97 minutes. "S," or the slope of the drying rate line, is now readily determined from the equation:

$S = 2W/T^2$, or

$S = 2 \times 19.8/12.97^2 = 0.236$

Once the S-value is known for any given set of conditions, the entire drying curve may be determined. An easy way of doing this graphically is illustrated in figure 8. It is necessary to use logarithmic cross section paper, and plot moisture content, in percent, on the vertical axis and "time to reach equilibrium," which is the reverse of time elapsed during the drying cycle, on the horizontal axis. We have already determined that the time to reach equilibrium, or in this case 0 percent content, is 12.9 minutes. The moisture content at the start of the drying cycle is:

$$\text{Moisture content} = \frac{81.8 - 62.0}{62.0} \times 100 = 32 \text{ percent}$$

These values give us one point in figure 8. At the other point, 9 minutes later, the time value is 12.9 — 9 = 3.9, and the moisture content is 3 percent. A straight line may now be

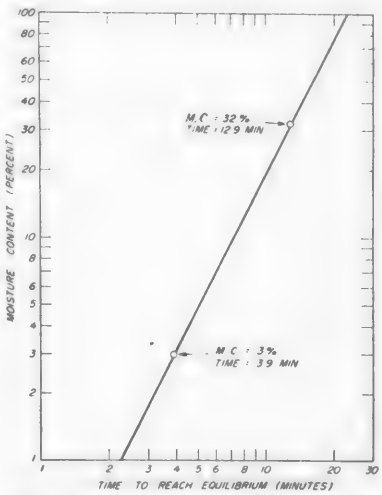

Figure 8.—Graphic method of deriving the drying curve from two known points.

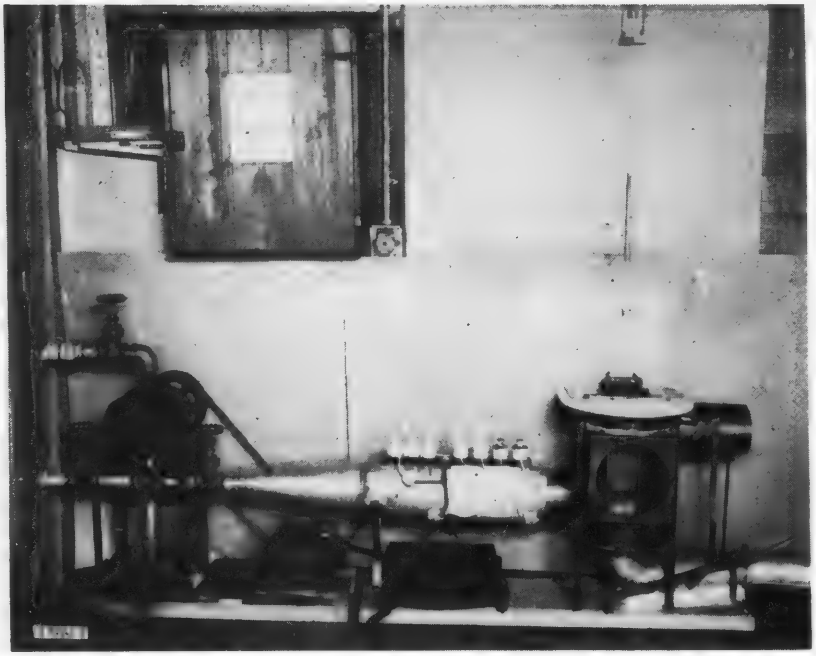

Figure 9.—The drying apparatus used in the tests before insulation was applied.

drawn through these points and the moisture content at any time during the drying cycle is easily read from it.

To use this curve properly, the drier operator must obviously know the moisture content of the veneer as it enters the drier. Adjustments in time schedules must be made to accommodate variations in initial moisture content of veneer. Bethel and Hader (1) have also pointed out that for the proper drying of veneer to constant moisture contents it is necessary to regulate the drier from the green end rather than from the dry end as is now commonly done.

Once a number of "S-values" have been determined for any drier and for any given species of veneer, interpolations to estimate drying rates at other conditions than those actually checked are easily made. For example, curves similar to those shown in figure 7 can be prepared and from them S-values for a wide range of drying temperatures and veneer thicknesses can be estimated. When plotting S-values over veneer thickness, drying temperature, or air velocity, logarithmic cross section paper should be used for the relationships may be expressed as straight lines on such paper.

The S-value may also serve as a practical means of evaluating the efficiency of one drier as compared to another. All of the factors at work in a commercial drier may not always be known. Air velocity over the veneer surface may be very hard to determine in some types of driers. Temperature may vary along the length of the drier, so that the empirical value determined by this practical method may actually represent the effects of a mixture of temperatures. Other factors that may vary from drier to drier are the amount of heat radiation from metal surfaces to veneer surfaces and the amount of heat transferred to the wood by contact with metal plates or rollers. S-values determined in commercial driers may therefore often be characteristic of individual driers, and may express the relative efficiencies of the driers in which they are determined.

How the Study Was Made

Most of the tests that form the basis for the study described here were of yellow-poplar heartwood. Two large old-growth logs supplied the test specimens which were 3 by 6 inches in size. All specimens were cut from a relatively small, homogeneous portion of the heartwood of each log so as to be as uniform as posisble. The logs were straight-grained and sections were first roughed out by splitting along the grain so as to eliminate crossgrain in the test pieces. The pieces were cut by sawing and planing so as to eliminate any possibility of checks on one surface, such as occur when veneer is cut with the knife, that might affect drying rates.

Thicknesses tested were $\frac{1}{32}$, $\frac{1}{16}$, $\frac{1}{8}$, and $\frac{1}{4}$ inch. Temperatures used in the tests were 150°, 250°, and 350° F. Air velocities were 200, 600, and 1,000 feet per minute parallel to the flat surfaces of the specimens. Two humidities were used, one a rather low absolute humidity of 0.029 pound of water per pound of dry air, and the other a very high absolute humidity 100 times this value (except for the 150° F. temperature, when the absolute humidity was 0.144 pound per pound of dry air). The total number of drying rate tests on yellow-poplar was 144. In addition, 36 closely matched specimens were dried to determine temperatures during the drying cycle.

Drying rate tests were also made on sweetgum and redwood heartwood specimens, of four thicknesses and at three temperatures, at an air velocity of 600 feet per minute and at low humidity only.

In order that all external conditions during the drying tests could be closely controlled, a special small drying apparatus was built. This is shown in figure 9. Humidity control was attained by drawing the air for the tests from a dry kiln, the door of which is partly visible at the left. The air was moved through the apparatus by a pump mounted on a metal frame at the left. The air velocity over the specimens was controlled manually by means of the valves seen on the various ducts leading from the pump. Air moving through the long tapered duct to the right of the pump passed over electric heaters mounted in the section on which the switches are seen (some of which were automatically controlled), and then into the drier plenum chamber, toward the right of the picture, with a round glass window at its front. In this chamber the air circulated slowly around and upward, then passed downward over the test specimen which hung in a small rectangular duct in the middle of the chamber. It too had a glass window in it, and a test specimen is seen hanging in the proper position for the drying test. The air leaving the test specimen was exhausted through the small round duct in the lower right hand corner of the picture. The inclined scale manometer mounted on the wall above the pump measured the air flow with the aid of sharp-edged orifices located at the end of the exhaust duct (not shown).

In order that the test specimens might be weighed at intervals during the drying to determine the rate of drying, it was necessary momentarily to shut off the flow of air over the specimen. This was done by pushing a lever that closed a damper on the lower exhaust duct and opened a damper on a larger exhaust duct from the plenum chamber, seen near the top and to the right of the chamber. The end-coated specimen was suspended by a thin flexible cable from a weighing spring, shown hanging in a glass tube over the drier chamber.

(Continued on page 91)

Storage of Northern Hardwood Logs and Bolts[1]

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Methods for reducing fungus deterioration in northern hardwoods is discussed. Various means including fungicidal sprays, end coatings, intermittent and continuous spraying, and immersion under water are considered. Data given shows that birch logs stored under continuous spray or under water will yield almost 50 percent high quality veneer. Quantity and quality of yield is comparable to freshly cut logs.

IN THE CONVERSION OF LOGS to forest products there is now and always will be a certain amount of unavoidable waste, resulting from the form of the raw material and from defects present in the living tree. Losses occurring after logging and before conversion, however, are largely preventable and there is little justification for the continued use of methods of storing logs that permit, even encourage, loss of merchantable volume and depreciated value during this period. It is the purpose of this paper to indicate briefly a few practices that will lessen or prevent such losses, with reference primarily to northern hardwood logs.

Deterioration of logs during storage is caused by end checking, attacks of insects, and chemical stains and fungi that discolor and decay the wood. Certain practices are effective against all these agencies for an entire year, others against only one or two or for shorter periods of time; hence the choice of methods for a particular mill or industry may depend upon the tree species involved, the length of the storage period, and the quality of wood necessary for the end product. Log storage losses may be avoided, reduced, or attempted in several ways: (1) by immediate conversion to lumber or other forest products, (2) by spraying with fungicides and insecticides, (3) by applying end coatings, (4) by intermittent spraying with water with or without a protective covering, (5) by continuous spraying with water, and (6) by immersion in water. Combinations of two or more of these methods may increase the effectiveness of the treatment. I shall discuss these various methods in detail later but first I should like to consider briefly the conditions affecting the deterioration of stored northern hardwood logs.

[1] Presented at meeting of the Forest Products Research Society, Northeast Section, May 7–8, 1953, at Portland, Me.

Most of the northern hardwood region lies north of the 44th parallel, which runs from a point just north of Portland, Maine, westward through central New Hampshire and Vermont, across New York from the southern end of Lake Champlain to Watertown, and through the Lake States from the thumb region of lower Michigan to just north of the southern boundary of Minnesota. The Division of Forest Insect Investigations of the United States Department of Agriculture has expressed the opinion that within this region the danger of insect damage to stored northern hardwood logs under normal conditions is not serious enough to warrant major consideration of insect preventive measures. In addition, some of the measures recommended for protection from fungus deterioration are equally effective in reducing or preventing damage by insects. For these reasons, no further consideration will be given in this paper to the problem of insect deterioration.

One of the well-known properties of wood is that it swells as it absorbs water and shrinks as it dries out. What is less well known about wood is that swelling and shrinking occur only when there are changes in the moisture content of the wood below the fiber-saturation point, which usually ranges from about 25 to 30 percent of the oven-dry weight of the wood (3).

In the wood in living trees and in freshly cut logs the moisture content is practically always above this point. For example, for the three principal species in the northern hardwoods group, average moisture contents are as follows, respectively for sapwood and heartwood: beech, 72 and 55 percent; yellow birch, 72 and 74 percent; and sugar maple 72 and 65 percent (4). When trees are felled and bucked, the cut ends of the logs tend to dry out, with the surfaces soon reaching moisture contents below 25 or 30 percent. As soon as this happens, shrinkage checks are formed and when the logs are exposed to dry air for long periods of time, these checks may become quite deep. Not only are these checks injurious to the wood in the logs but also they offer ready access to the spores (seedlike reproductive bodies) of wood-staining and -decaying fungi. These spores germinate and grow into the wood far beyond the depth of the checks, rendering large volumes of wood unusable for quality products. In unprotected southern hardwood logs, wood-staining fungi have penetrated to a depth of about one foot in three weeks and three feet in three months (5). Decay fungi apparently penetrate less rapidly but are known to be well established in logs within a few weeks. In northern hardwood logs the rate of fungus penetration is slower, probably because of lower temperatures, but even here unprotected yellow birch logs may be invaded by fungi to a depth of more than one foot in one summer season. This indicates the seriousness of the situation and the need for improved storage methods.

Value Reduced

Invasion of wood by staining fungi has little effect on the strength properties of the wood but greatly reduces its value for uses where a natural finish is desired. Invasion by fungi that cause decay, however, is accompanied by strength losses that render the wood unfit for many purposes. The reason for this difference is that staining fungi live on the cell contents whereas decay fungi live on the wood substance itself, actually breaking down the structure of the wood.

Wood-staining and -decay fungi have definite moisture, air, and temperature requirements for growth (1). Fungus activity in wood cannot start when the moisture content is below the fiber-saturation point, above which there is a wide range of moisture contents at which fungi can grow vigorously. Fungi require air as well as moisture for growth; roughly speaking, about one-fifth of the volume of wood must be occupied by air before fungus growth can take place. This means that when an excess of water

is present in wood, as when it is waterlogged, decay is inhibited just as effectively as when insufficient moisture is present. The denser the wood is, i.e., the higher the specific gravity, the lower the moisture content at which decay is inhibited.

Temperature exerts an equally strong influence on fungus activity in wood. There is little or no growth at temperatures below 40° F. or above 120° F. Midway between these two extremes, approximately from 70° to 90° F., wood-staining and -decay fungi grow at maximum rates, with their activity tapering off as the temperature falls or rises toward either limit. Because of low temperatures during the winter months in the northern hardwood region, protective measures against fungus deterioration are needed only from April to October. This does not mean that nothing should be done until the onset of hot weather. Actually, protective measures should be initiated as soon after felling as possible, and their efficiency during mid and late summer largely depends upon whether they are applied before fungus infection occurred.

Immediate Conversion

Immediate conversion of logs into lumber or other forest products permits early seasoning of the wood to moisture contents below the fiber-saturation point, under which condition it may be stored indefinitely without fungus deterioration. Any practices that tend to shorten the time interval between felling and milling, such as speeding transportation to the mill, reducing log supplies, and using logs in the order in which they were stored, are steps in the right direction. However, economic considerations limit the application of such techniques, particularly in the case of large firms that use several million board feet of logs annually. Small mills in the northern hardwood region may find it economically feasible to schedule operations so that logs are never stored more than a few weeks, or at most two months, during warm weather and thereby greatly reduce log storage losses.

Fungicidal Sprays

As indicated previously, damage by insects to stored logs in the northern hardwood region ordinarily is not serious enough to warrant the expense of precautionary measures, hence this discussion is limited to the use of fungicides for log protection. The simplest use of fungicides is to spray them on log or bolt ends with a small garden-type sprayer. Various products, such as Dowicide G, Melsan, Noxtane, Permatox 10–S, and Santobrite, have given limited protection to logs when properly applied at the concentrations recommended by the manufacturers (6). The limitations of the use of fungicidal sprays alone are obvious. The spray must be applied at the onset of warm weather and at best only retards fungus infection, because checking of the ends of logs exposes the interior to infection, even though the surface is adequately protected. Spraying can be recommended only for comparatively short storage periods.

End Coatings

The purpose of applying end coatings to logs and other wood products is to retard evaporation and thereby reduce or prevent the formation of checks. Satisfactory end coating materials must provide a moisture barrier, adhere tightly to the end grain, withstand ordinary handling abuse, be flexible enough to adjust to changing wood dimensions, and be cheap enough that their cost does not exceed the value of the wood protected (2). These diverse requirements are difficult to meet; therefore, no completely satisfactory end coating has yet been devised. Several hot coatings have been tested, ranging from paraffin to pitch and asphalt compounds, but they are of questionable value for logs. A great many cold coatings have been tried, including white lead and aluminum paints, drying and filled hardened gloss oils, varnishes, synthetic resins, and asphaltic emulsions and cutbacks. Cold coatings are more appropriate for use on logs than hot coatings and in general have given better results, particularly heavy asphaltic preparations.

A combination of spraying with fungicides followed by end coating immediately with the most satisfactory materials gives better protection than either practice alone; in fact, logs can be successfully stored by such methods for a full summer season, from spring through fall. Regardless of the efficiency of the treatments, however, fungus infection eventually will be introduced through the bark by direct penetration, by boring insects, and through cracks or other openings.

In addition to log deterioration by end checking and by fungi, an objectionable yellowish-brown to rust-colored stain commonly occurs in birch logs stored during warm weather. Like decay, it progresses inward from the ends of logs and may penetrate rather deeply in a few weeks. It has been referred to as chemical stain and probably is caused by oxidation of the wood constituents on exposure to air. Good end coatings reduce but do not eliminate such stain. It is probable that high temperatures in summer-stored logs exposed to full sunlight favor the progress of this stain.

Intermittent Spraying with Water

The effectiveness of water as a protective covering for logs and bolts has been appreciated for many years, without adequate distinction between the effectiveness of different methods of application. There is no straight line relationship between the quantity of water applied and its protective value to wood. Apparently, some individuals have reasoned that if a lot of water does a lot of good, then smaller quantities must also have proportional protective value. The truth of the matter is that water applied in small quantities to stored logs or bolts may actually increase the damage rather than reduce it. Logs must be soaked or submerged to really protect them and any lesser treatment is of questionable value. Some pulp and paper mills have wetted stored softwood bolts by intermittent or periodic spraying with water, with disastrous results. Similar attempts to protect hardwood bolts and logs have failed. Recently, however, end checking and decay losses in beech, birch, and maple turning bolts have been greatly reduced at one mill in Maine by storing them on end over cleared land in the winter as soon as they are received at the mill and covering them with hay that is wet down from time to time during subsequent warm, dry weather. The hay, acting as a wet blanket and a heat insulator, prolongs the time during which the bolts remain unfavorably cold for decay. The high humidity under the hay also reduces end checking. It is reasonable to expect that spraying the bolts first with a good fungicide might increase the effectiveness of this practice.

Continuous Spraying with Water

The lack of success in protecting logs with intermittent water sprays undoubtedly has discouraged further experimenting with continuous sprays and has strengthened the belief that the only really safe way to store hardwood logs is to submerge them in water. A few years ago a large hardwood veneer mill in Maine, using yellow birch almost exclusively, was faced with the necessity of increasing its yield of high quality veneer per unit of logs if it hoped to maintain its position in a highly competitive industry. Current logging practices necessitated the accumulation of sufficient logs during the winter to operate the mill through the following summer months. By mid to late summer,

decay caused excessive losses in logs stored in conventional dry decks. Curtailing these losses offered the best way to increase the yield of veneer; therefore, appropriate steps were taken. Four storage pits, about 200 feet by 50 feet and 20 feet deep, were dug in the mill yard, lined with clay, and filled with water pumped from an adjacent river. About two million board feet of yellow birch logs could be submerged in these pits. Even this amount was inadequate for the storage needs, hence logs were piled on top of the pits, about as many out of water as under it, and were sprayed continuously from mid-April to mid-October. The officers of this mill have very generously furnished information on storage under these conditions and have agreed to publication of the following details, as a guide to other mills interested in similar storage methods.

Water for the sprayers was pumped from the river at the rate of 500 gallons per minute under 120 pounds pressure per square inch. On each of the four log decks six one-inch "rain bird" sprayers, pulsation-actuated rotary type, were mounted, one at each end and four in the middle. The four decks had a combined basal area of 40,000 square feet over which 500 gallons of water per minute, or 30,000 gallons per hour, were sprayed. This amounted to ¾ gallons of water per hour per square foot, equivalent to a rainfall at the rate of 1.2 inches per hour. Even when allowances are made for inequalities in the distribution of the spray, it is not unreasonable to assume that these log decks were sprayed with the equivalent of one inch of rainfall per hour. The spray was sufficient to keep the pits full of water, completely submerging the logs in them, and to keep the exposed logs well soaked all of the time. Detailed information on the effectiveness of such storage will be given later.

Immersion under Water

All species of logs and bolts, including those from northern hardwoods, can be held practically in their original condition by storing them in fresh water shortly after cutting, or at least before the onset of summer temperatures considerably above the safe 40° F. level. Yellow birch veneer logs sunken in mill ponds were recovered by grappling during the last war years. No records were available as to how long these logs had been so stored but there is no doubt that some of them had been there for several years. Except for a slight darkening of the sapwood and a slightly objectionable odor, these logs were in excellent condition. Yellow birch bolts stored under running fresh water in New Hampshire for nine months, from February through October, were entirely free from any degrade, whereas comparable bolts stored in open ricks were badly checked and decayed an average distance of 8 inches inward from each end. At the veneer mill in Maine referred to previously, yellow birch logs stored under water were adequately protected, some logs for two years or longer.

Underwater log storage prevents checking from seasoning and halts decay and stain by cutting off the air necessary for fungus growth. Brackish or salt water is unsafe because of marine borers. Storage for one season should result in no objectionable discoloration or odor. Insect injury is completely eliminated as well as other types of deterioration.

Table 1.—VENEER YIELD FROM FRESHLY CUT YELLOW BIRCH LOGS AND FROM LOGS STORED UNDER CONTINUOUS SPRAY AND UNDER WATER

Log and veneer data	Controls	Storage methods		
	Freshly cut logs	Under spray 6 months	Under water 1 year	Under water 2 years
Yard scale, bd. ft.	22,735	22,570	11,875	12,750
Veneer yield per M.				
Face quality, sq. ft.	5,116	4,923	4,663	4,838
Back quality, sq. ft.	5,189	5,657	6,155	6,396
Block scale at lathe, bd. ft.	26,766	25,311	12,403	13,708
Veneer yield per M				
Face quality, sq. ft.	4,345	4,390	4,465	4,500
Back quality, sq. ft.	4,408	5,044	5,893	5,949
Face quality veneer, percent	49.6	46.5	43.1	43.1
Log waste at trim saw, bd. ft.	4,462	4,474	1,740	2,374
Percent of yard scale	19.6	19.8	14.7	18.6

Comparison of Results of Water Storage

It is difficult to make exact comparisons of the relative efficiency of various storage techniques. In manufacturing veneer from hardwood logs some unavoidable waste arises because bolts must be cut from the logs, end trimmed, and rounded off on the lathe before usable veneer is produced. Later the veneer is again trimmed according to panel sizes needed and to remove open knots and other defects. In these operations there is a tendency to erase the differences between logs of different qualities, largely because it is immaterial whether log volume lost in cutting bolts and trimming veneer is of high or low quality. Nevertheless, there is always a quantitative difference in the quality of the veneer cut from fresh or well-stored logs and from logs that have been allowed to end check and decay. For this reason, in the present study the criteria for comparison of different storage methods are the yield of veneer suitable for faces and for backs in square feet per thousand board feet of logs as scaled in the yard and at the lathe, and the percentage of this veneer that is of face quality. Unfortunately, poorly stored logs with serious checking and decay were not available so that comparisons can be made only between freshly cut logs and those stored under continuous spray and under water. Data are presented in Table 1 on the veneer yield from winter-cut yellow birch logs that were (1) freshly cut and converted immediately, (2) stored under continuous spray from mid-April to mid-October, (3) stored under water for one year, and (4) stored under water for two years.

The most significant comparison in this table is the percentage of veneer produced that is of face quality. From the freshly cut logs 49.6 percent of the veneer produced was of face quality, from those continuously sprayed throughout the summer months 46.5 percent, and from those stored under water for one and two years 43.1 percent. Moreover, the actual yields of face quality veneer in square feet per thousand board feet scale at the lathe, were greater for the stored logs than for those that were immediately converted. The explanation for this probably is that the logs in the particular test runs varied enough in original quality to give these results.

Conclusions

The principal conclusion from these data is that storing yellow birch veneer logs under continuous spray or under water holds them for all practical purposes almost in their original condition. Both of these methods merit much wider use than they have had in the past. The experience of the company that contributed the data has completely sold them on continuous spraying as an alternative for underwater storage. By either method they can be assured that almost half of the veneer they cut will be of high quality; furthermore, the yield will be comparable in quantity and quality to that from freshly cut logs. What more can you ask of any storage method!

Literature Cited

1. Boyce, J. S. 1948. Forest Pathology. 2nd Ed. xi + 550 p., illus. McGraw–Hill Book Co., N. Y.

(Continued on page 92)

Lumber Stains and Their Control in Northern White Pine[1]

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The common stains of northern white pine lumber are described, their causes indicated, and control measures presented in regard to logging and milling practices in the Northeast. It is emphasized that in special cases such as interior stain or solid piling, chemical dipping should be made within 24 hours.

NORTHERN WHITE PINE (*Pinus strobus* L.) logs and lumber frequently developed stains and discolorations which reduce product values considerably. Losses from stains have increased in recent years in the Northeast due to extensive summer logging and to the greater amounts of sapwood in lumber as smaller diameter logs are utilized. Changes in handling practices such as package piling and use of concentration yards also favor the development of stain in many cases.

The change in the appearance or reduction of the aesthetic quality of boards by stain is particularly important in pine where natural finish uses are common. Although in general stained wood suffers only slight strength losses, such wood may contain incipient decay with important strength losses. Recent studies (13) have indicated that stained wood in exposed positions in buildings sometimes decays more rapidly than unstained wood. For these and other reasons, increased consumer prejudices and resistance to purchase and use of stained wood can be anticipated.

White pine lumber enjoys an excellent reputation among our native woods. Stain control will enable it to retain this position.

Simple, economical, and effective methods to control lumber stains have been developed (9, 15) and are in use in many sawmills throughout the country. Satisfactory stain control for white pine in the Northeast can be achieved by applying these proven methods. In this paper, the common stains of white pine are briefly described, their causes indicated, and basic information on control reviewed.

Stains Caused by Fungi

Many of the important stains and discolorations that develop on white pine logs or lumber are caused by the growth of fungi in or on the wood. Common discolorations on pine are blue, gray, black, brown, and pink to red. The subsequent stain descriptions are based for the most part on studies of hundreds of samples of discolored logs and lumber collected from sawmills and seasoning yards located in New York.

Blue stains: The most frequent stain on white pine is a bluish discoloration in the sapwood of lumber and logs. This discoloration is so common that in general the term "blue stain" has come to refer to any dark discoloration in the sapwood caused by fungi. The stain varies in intensity and extent with periods of exposure and favorable or non-favorable staining conditions. In mild stain occasional longitudinal streaks are observed, whereas in severe stain the entire sapwood of a board may be deeply discolored and black streaks are evident in resin canals and exposed rays. These discolorations are deeply penetrating and may develop in logs or in boards when rapid drying is retarded and favorable conditions for growth of fungi occur.

Many fungi cause the sap stains in white pine. Those generally causing the bluish discolorations in white pine are members of the genus *Ophiostoma* with *Ophiostoma coeruleum* (Münch) Syd.[1] as the commonest species. Other fungi commonly associated with grey and black stains belong in the genera *Alternaria* and *Leptographium*.

Brown stains: A chocolate-brown stain is known to develop frequently in the sapwood of several pines in eastern Canada during storage (3). This chocolate brown sap stain has been observed commonly in logs of white pine within recent years in New York. The stain penetrates a board deeply and numerous dark flecks appear in the wood rays. The discoloration develops primarily in stored logs. It is found near log ends or in areas where debarking has occurred and is caused by a fungus identified as *Cytospora pini* Desm.[2] Since this discoloration has frequently been confused with a brown chemical stain known in the Northeast as "coffee stain," the following macroscopic differences are listed:

a) brown stain is limited to sapwood, whereas coffee stain commonly discolors both heartwood and sapwood.

b) brown stain is surrounded by wood of normal color, whereas coffee stain usually is bordered by lighter whitish zones.

c) brown stain develops primarily in stored logs, whereas coffee stain develops mainly in lumber during kilning.

Pink to red stains: A pink to intense reddish discoloration observed in freshly sawed white pine lumber is often an early stage of the red ring rot caused by *Fomes pini* (Thore ex Fries) Lloyd. The discoloration develops in the living tree and is generally confined to the heartwood. The defect is readily recognized by the small spindle-shaped white pockets of decay found in areas of advanced decay or in knots. These discolorations are generally found in lumber from logs bearing external indications of the red ring rot such as punk knots, resinosis, or conks of F. *pini*.

Surface discolorations or molds: Practices resulting in retardation of drying, such as solid piling, favor development of surface discolorations caused by molds. Common discolorations are green, purple, red, and black. As a rule, the discolorations occur on the surface of the board in localized spots and are removed during planing. The sap-stain fungi are usually found growing with the molds, however, and their discolorations cannot be removed by surfacing. Species of *Penicillium, Fusarium, Trichoderma*, and *Aspergillus* are common molds occurring on northern white pine.

Within recent years, two molds, *Penicillium cyclopium* West and

[1] Presented at meeting of the Forest Products Research Society, Northeast Section, May 7–8, 1953, at Portland, Me.

[1] Grateful acknowledgment is due Mr. Ross Davidson, Division of Forest Pathology, U.S.D.A., for aid in identification of certain wood-staining fungi.

[2] Identification was made by Centraalbureau voor Schimmelcultures, Baarn, Holland.

Penicillium crustosum Thom have been observed to cause a deeply penetrating, blue-mottled stain of white pine (2). These fungi exhibit an unusual tolerance to organic mercury compounds and have been found on lumber treated with anti-stain compounds containing the organic mercurials as the toxicants.

Chemical Stains

An important group of stains in white pine lumber result from chemical changes which take place during seasoning. These stains are not the result of fungous activity and are known as chemical stains. One of the important discolorations of this type in white pine is a chocolate-brown stain generally called "coffee stain".

Coffee stain: This serious chemical stain of white pine is characterized by yellow to dark brown discolorations, generally in the sapwood and heartwood of kiln-dried lumber. Frequently margins of bleached wood surround the discolorations, particularly at the ends, or near board surfaces, or between heartwood and sapwood. The stain develops occasionally in logs during storage or in lumber that is air-seasoned, but is more serious in kiln-dried lumber. The stain develops on the surface and inner portions of the board. Occasionally surfacing of apparently "bright" boards exposes the internal coffee stain. Studies of a similar stain on sugar pine suggest that sugars and related substances are concentrated and brought to the wood surface during drying. Under certain conditions these substances are discolored and produce the characteristic defect known in the trade as coffee stain (7).

Control of Coffee Stain

Extensive field studies on the control of coffee stain on northern white pine are not known to the writer. This chemical stain appearing on western species of white pine has been thoroughly investigated (8, 10) and the practices found effective may prove useful also for northern white pine. The studies indicated that three times as much coffee stain appeared on old logs (stored 9 months) as in freshly cut logs (stored 9 to 10 days). Also storage of lumber in solid piles after sawing was shown to be an important factor favoring the formation of coffee stain. Shortening the period of log storage and limiting periods of solid piling of freshly sawed lumber to a day were effective in reducing coffee stain damage. These same practices help to control sap stains during warm seasons. Moderate kiln schedules have been found to further minimize the development of coffee stain (4, 11).

Control of Sap Stains Caused by Fungi

Stain problems on white pine are most serious in the Northeast in the warm season, approximately from May 15 to September 30 varying somewhat with location and kind of weather.

A practice wisely followed for years in the Northeast has been to log white pine and saw it into lumber when practicable during the colder seasons of the year. As a general rule little sap stain is observed in pine lumber properly piled before May 15.

The kilning of freshly sawed lumber within three to four days of sawing is another handling practice used to insure freedom from sap stain in the higher grades. It is necessary, of course, that the logs be free of stain.

In certain mills the control of sap stain is attempted by rapidly seasoning the boards by special piling methods such as end-racking or triangular piling. With poor seasoning weather these methods are not effective. During the severe staining season of 1951 heavy discolorations developed in lumber seasoned in New York by these methods. These piling methods should be considered as primarily a means of shortening the seasoning period. They are, however, very effective in the control of sap stain as are the conventional flat piling methods when used in conjunction with dip treatments in stain-preventive chemical solutions.

To insure sap stain control, pine lumber sawed during the warm season should be dipped in stain-preventive chemical solutions and immediately piled so as to season rapidly. It must be emphasized that neither treatment alone will guarantee success in the Northeast. The chemical treatments prevent the growth of fungi on the surface of the seasoning board until the exposed surfaces have dried to a moisture content of approximately 20 per cent based on oven-dry weight, which is lower than that required for growth of stain fungi.

The practices and precautions essential to successful use of toxic chemicals to control sap stain are well known. These procedures are summarized briefly for northeastern conditions. Successful control programs must be based on sap stain control in the log and in the seasoning pile.

Log Stain Control

Stain in lumber seasoned in the Northeast often originates in the log. It is necessary that stain-free logs be obtained at the sawmill if subsequent dipping treatments and rapid drying practices for stain prevention are to be successful.

Rapid utilization of the log in the summer reduces log stain. Under ideal staining conditions serious amounts of stain develop in logs stored over ten days. After sawing the stain continues to develop in the seasoning board. In addition stained logs serve as an important inoculum source of boards during sawing.

Ponding of pine logs is an effective method of eliminating the development of log stains. Ponding experiences with white pine logs salvaged during the 1938 hurricane in New England attest to the effectiveness of this storage method. In northern New York logs which were ponded throughout the summer season were stain-free when sawed in the fall.

In cases where summer storage is necessary and ponding facilities are not available, chemical spray treatment of logs has been found effective (1, 15). Success with these recommended treatments of logs depends on promptly spraying the logs within 24 hours after felling. Successful control in summer-stored logs in the Northeast also depends partially on insect control since several of the important staining fungi are largely insect disseminated. Treatments are available for controlling insect damage in stored logs (6).

Stain Control in Seasoning Lumber

Treatment methods: In the Northeast lumber sawed from stain-free logs, promptly dipped in effective stain-preventive solutions and properly piled for rapid seasoning, will dry practically stain-free. The methods of treatment, kinds of chemicals, sources, and handling procedures insuring control have been presented by many workers (5, 9, 12, 15).

In brief, the freshly sawed lumber should be dipped within 24 hours after sawing in effective stain-preventive solutions. At small mills dipping is acomplished in homemade wooden tanks or steel tanks made of welded oil drums. In larger sawmills automatic dipping vats have been found efficient and effective. Plans of these vats are available upon request from most of the companies selling stain-preventive chemicals. Careful attention should be paid to maintaining effective concentrations of chemicals in the treating vats. Continuous dipping of lumber selectively removes mercurials. It is recommended that treating solutions of mercurials have additional solution added whenever the contents drop below 80 per cent of original volume (14).

Protection of the treated stock from rain and prompt placement in well-located seasoning piles is necessary.

Specific recommendations on the size of piles, spacing, alignment, stickers, and pile covers have been adequately discussed in several publications (5, 9, 15).

Choice of stain-preventive chemicals: Many effective chemicals for stain control are available on the market. Tests conducted on white pine seasoned in New York indicate proprietary compounds such as Permatox 10–S, Melsan, Noxtane, Santobrite, and Dowicide G are effective at their recommended concentrations. These tests did not include all useful proprietary compounds but were limited to those sold in greatest volume at the time of the test. The proprietary names are presented with no implication of specific endorsement. Compounds containing ethyl mercury phosphate as the single toxicant are not effective in controlling deep staining molds. These stains are described in detail under the section on molds.

A simple method of determining the relative effectiveness of various stain compounds for use at a mill has been described (16). This method requires no extensive equipment and determines the relative effectiveness of the toxicants as evaluated by the staining flora of a specific mill.

Treatment costs: Dipping treatment of 4/4 lumber consumes approximately 15 gallons of stain-preventive solution per 1000 board feet. This figure is slightly lower for thicker stock and when drain boards for treated lumber are used. At current prices for proprietary stain-preventive compounds, the cost of chemicals for treatment is in the price range of 15 to 20 cents per 1000 board feet. In the larger mills the additional cost of treating tanks is very small when prorated over a large lumber volume. In smaller mills using hand dipping in wooden vats, or welded oil drums, the laborer's wage must be included in the cost of treatment.

Special Stain Problems

Interior stain: Under some conditions the interior of a board may be severely stained without any color appearing on the outer surfaces. Such stain, termed interior stain, appears during resawing or surfacing. It results usually from excessive delay in chemical dip treatments after sawing, by rapid drying. Delay in lumber dip deep stain which originated in the log, or a delay in air drying followed treatment at concentration yards sometimes results in undue amounts of interior stain. Where such delays exceed 24 hours it is recommended that dip treatments be made at the small sawmills prior to transporting to concentration yard for grading and seasoning.

Protection during solid piling: Solid piling of freshly sawed pine prior to seasoning and for short transportation periods is common practice. In those cases of solid piling where chemical dipping treatments are delayed more than 24 hours or not used, serious stain develops if air seasoning is attempted. Solid piling of chemically dipped lumber to be kiln dried is safe for several weeks if treating concentrations of chemicals are doubled (15).

Literature Cited

1. Anonymous. 1949. Prevention of deterioration in stored southern hardwood logs. Southern Forest Expt. Sta., U. S. Dept. Agr. Mimeographed.
2. Brown, F. L. 1951 Mercury tolerant Penicillia causing stain in northern white pine lumber. College of Forestry, State University of New York, Syracuse, New York. (Unpublished thesis).
3. Fritz, Clara W. 1952. Brown stain in pine sapwood caused by Cytospora sp. Canadian Journal of Botany 30:349–359.
4. Hoyle, Robert J. Jr. 1951. Report on examination of kiln drying schedules for northern white pine. Unpublished report for the Burritt Lumber Sales Co., Bridgeport, Conn.
5. Krause, Robert L. 1950. Reducing blue stain losses in lumber. Southern Lumberman 181 (No. 2265): 45–54.
6. MacAndrews, A. H. 1953. Prevention and control of Ambrosia beetle damage to wind thrown timber. New York Forester, Vol. 10, No. 1.
7. Millett, Merrill A. 1952. Chemical brown stain in sugar pine. Journal of the Forest Products Research Society 2:232–236.
8. Rasmussen, C. A. 1951. Age of logs as related to kiln brown stain of sugar pine. Western Pine Association Research Laboratory Note 28. (Revised).
9. Scheffer, T. C. and R. M. Lindgren. 1940. Stains of sapwood and sapwood products and their control. U. S. Dept. Agr. Tech. Bul. 714:1–123.
10. Stout, A. W. 1950. Storage factors and occurrence of chemical brown stain in sugar pine. Western Pine Association Research Laboratory Report No. 39.
11. Torgeson, O. W. 1951. Schedules for kiln drying of wood. U. S. Dept. Agr., Forest Service, Forest Products Laboratory No. D 1791.
12. Verrall, A. F. 1945. The control of fungi in lumber during air-seasoning. Bot. Rev. 11:398–415.
13. ———— 1951. Permanence for wood siding. U. S. Dept. Agr., Forest Pathology Special Release No. 36.
14. ———— and P. V. Mook. 1950. Adsorption of sap stain and mold-control chemicals by wood. Indus. Engin. Chem. 42:1350–1355.
15. ———— and T. C. Scheffer. 1949. Control of stain, mold, and decay in green lumber and other wood products. Proceedings Forest Products Research Society 3: 480–488.
16. Zabel, R. A. and C. H. Foster. 1949. Effectiveness of stain control compounds on white pine seasoned in New York. N. Y. State Col. Forestry Tech. Pub. 71.

RESPONSIBILITY FOR RESEARCH

Rethinking of present division of research responsibilities is recommended by Julius A. Stratton, vice-president and provost at Massachusetts Institute of Technology, Cambridge, Mass. "Traditionally, we have looked to the universities for the advancement of knowledge, and we depend upon them largely for all research into the fundamentals of science. To industry falls the task of applying new knowledge to useful ends and of furthering research and development focused on new materials, processes, and products. . . . Government encourages research of all kinds with a view to development of new weapons and supports a variety of investigations in such fields as agriculture and pubic health. But all this chain of obligations hangs upon fundamental research, and the future vitality of countless enterprises depends upon the soundness of our national effort in this domain. The responsibility for the suppport of basic science cannot be delegated wholly to the university; it must be shared by industry and government, by business and by the public at large."

Wood-Residue Collection Techniques[1]

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As the demand for products made from wood residues increases, economical methods for collecting such residues becomes increasingly important. Various methods for collecting and storing both course and fine materials are described, as well as factors affecting transportation of such materials.

Introduction

METHODS OF COLLECTING wood residue are becoming increasingly important because means of converting this material to usable products are being developed. In some cases these developments are not new to research but are new to industry because economic conversion was not formerly possible. One of the major items that determines the economic feasibility of conversion processes is handling costs. This is particularly true of wood residue. Some conversion processes have been established because residue disposal was an expense item, whereas conversion eliminated the expense and sometimes produced a slight profit.

Our expanding population and resulting increased use of fiber products are increasing the demand for raw material. Although improved forest management increases the supply of wood, a large volume of wood is already available in the form of wood residue left from the harvesting and manufacturing of wood products. Data compiled from various parts of the country indicate that about half a cord, or nearly 1 ton, of wood residue is produced for every 1,000 board feet of lumber sawed. The production of other wood articles leaves varying amounts of residue, depending upon the degree of manufacturing. On the basis of this information, the lumber industry alone produces about 16 million tons of coarse usable wood residue per year. This volume, plus sawdust, logging slash, and residue from other wood-using industries, indicates the magnitude of the wood-residue handling problem. In addition, this residue is not concentrated. It is produced at locations scattered throughout the entire country. Therefore, in many instances, conversion plants must collect the wood residue from a number of locations. Methods used for collecting, handling, and transporting this raw material are dependent upon the size, shape, and mixture of the raw material.

Wood-residue Classification

Wood residue can be considered in two broad classes—coarse and fine. The first category includes slabs, edgings, end trimmings, logging slash, and other solid forms. The second class includes sawdust, shavings, chips, and similar material. It is necessary to consider these two classes separately because equipment and methods used for one are sometimes not suitable for the other.

Coarse Residue

Although there is a great deal of interest in all types of coarse residue, the one that is of the greatest interest is the coarse residue developed by sawmills in the form of slabs and edgings. Material of this type is generally diverted to single-conveyor systems leading to the refuse burner. Although feeder systems frequently use belts, the main conveyor is more often a chain type. Generally, all material, both coarse and fine, is diverted to this main conveyor.

Now that serious consideration is being given to residue utilization, it is necessary to segregate coarse and fine residue. Since the major use of sawmill residue at present is for conversion to pulp chips, it is necessary to recover the coarse and discard the fine material. To date, this has been accomplished at most mills by using separate conveyor systems for coarse material and sawdust. It is possible, however, to equip the present chain conveyor system with perforated steel plates so as to screen out the sawdust and similar fine material. Similarly, short pieces under 12 inches in length can be diverted into storage bins, leaving the long desirable lengths of slabs and edgings to be conveyed on to the end of the conveyor. To date, insufficient attention has been given to mechanical means of sorting material along the conveyor chain. Most of the mills recovering material today use labor to hand-pick large-size solid material from the conveyor chain or to select small undesirable material by hand from the chain and to allow the other material to pass on.

After the solid material has been segregated, it must either be trans-

Figure 1.—Typical wood waste produced at sawmills and presenting a problem to collect economically.

[1] Presented at meeting of the Forest Products Research Society, Northeast Section, May 7–8, 1953, at Portland, Me.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

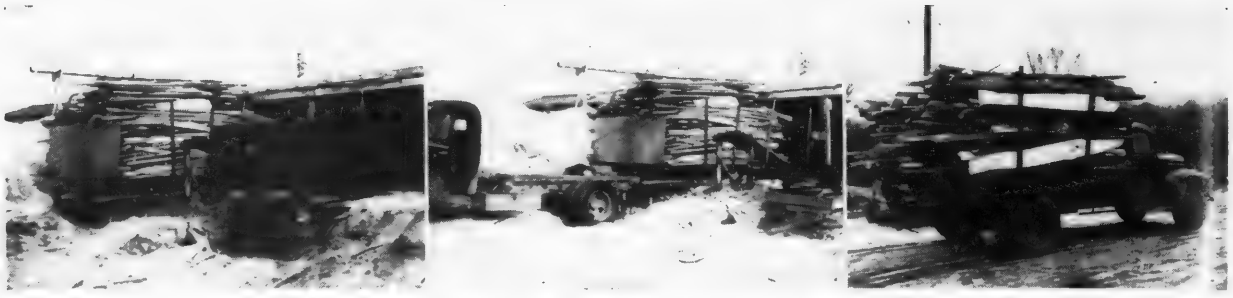

Figure 2.—Slab loading method cuts truck turn-around time.

ported in its present form to a centralized plant that will produce chips or it must be chipped at the sawmill itself. If it is to be chipped at the sawmill, then the conveyor terminates just above the chipper and the material is gravity-fed down a spout into the chipper mechanism.

Material that is to be transported from the sawmill in its original condition, that is, in solid form, should be assembled into bundles as quickly as possible to reduce handling charges. Two methods are commonly used. One is to pass the slabs and edgings through a slasher-saw system that reduces the material to uniform 4–foot lengths. These 4–foot lengths are then bundled with wire in amounts of approximately 1–cord bundles. The other system is to take the material in its original condition and pile it into racks or onto trucks that have divider stakes so that two bundles are formed, one on each side of the truck. Each of these is then bound together with wire so that any further handling can be done with lift trucks. Bundles in either short or long lengths can be handled by lift trucks at the end of the transportation haul. At that point the bundles are removed from the trucks, placed on conveyor chains going to the chipper, and the bundles are broken down just before they reach the chipper so that the material can be shunted into the chipper in the usual manner. Very short, coarse material is generally conveyed into bins and emptied from the bins by chute into trucks or railroad cars to that the handling is entirely mechanical; whereas, with longer chippable coarse material, some handling by manpower is generally done, although it is very important that as much of this as possible be eliminated and that the material be handled in bundles so as to keep down the labor costs.

Fine Material

Fine material, including sawdust, chips, and the like, can be handled by chain conveyors or belt conveyors, or by pneumatic systems wherein the chips are blown for considerable distances. At sawmills practically all of the sawdust is handled by chain or pneumatic conveyors, although some belt conveyors are in use. On the other hand, chips produced at sawmills or chipping plants are conveyed by belts and pneumatic systems more commonly than by any other means. Pneumatic systems have the advantage of being quite flexible in that they can be shortened or lengthened more readily than chain or belt conveyor systems. Likewise, such systems can be used for changing direction of flow more readily than can be done with the other systems. Fine materials have the advantage that they can be bulk-handled more readily and with less hand labor than can the coarse materials.

Bundling or baling of fine material, on the other hand, is very difficult, with the exception of shavings. Shavings, being of nonuniform character as to size, can be baled in the normal manner with little difficulty. Pulp chips, sawdust, and other material where uniformity of size is one of the specifications, do not bind and will not bale without additional difficulty and the adding of paper, cloth, or some other material on the outside of the package so as to confine the contents. For this reason, the bulk handling of fine material by truck or railroad cars is not only desirable but necessary.

Where it is necessary to meter the flow of material, as is often the case, it is relatively easy to do so with fine material, whereas it is a difficult process with coarse material. This brings into the picture a new method of conveying not previously mentioned, and that is the screw-type conveyor. This conveyor makes it possible to regulate the flow of chips being fed out onto other conveyors or into production machines. Regulation of material flow rate is one of the major advantages of the screw-type conveyor system. Where a constant flow of material is not essential but the amount passing in a given time must be known, then weight meters can be installed on belt conveyor systems.

Sometimes material must be elevated vertically because of space limitations. Pneumatic or bucket-type conveyors are both suitable for this application. Although the maximum rate of flow can be controlled by bucket conveyors, it is difficult to control the flow at slower rates.

One or more of these conveyor systems must be used at the point where manufacturing wood residue is produced. Quite frequently, bins with gravity chutes are used to load transportation vehicles, but conveyors must be used to elevate the material to the bins.

Transportation

Since the source of supply of wood residue is small at any one location, it is necessary to collect the material at these scattered locations and concentrate it at a central point before it can be processed. This involves handling and transportation and the problems connected with them. These problems are generally considered in three categories—handling, weight, and volume—and each causes various problems that must be solved.

Mechanical handling, of course, is much cheaper than handling individual pieces or small quantities. In order to handle material mechanically, the volumes must be relatively large for each movement of the mechanical equipment. Therefore, bundling of coarse material and flow systems for fine material are essential.

Weight

Although a considerable number of transactions are made on a weight basis, it is necessary in calculating transportation costs to know the amount of space required to hold a

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Figure 3.—Tractor mounted bucket loads scrap wood.

Advances in Integrated Logging[1]

FLOYD M. CROCKER
Woodlands Manager, St. Regis Paper Co., Bucksport, Maine

Describes company experience in integrated logging, stressing importance of physical properties in relation to using wood to best advantage. Woods operations as related to log length, end use of logs, and transportation of logs to mill are discussed. Alertness to changing market conditions is still another factor that influences integrated logging methods.

IT HAS BEEN SAID that the St. Regis Paper Company, and its predecessor, have practiced integrated logging for a longer period of time than any of the other larger timber companies in the United States.

The properties that we have on the Machias River and in the village of Whitneyville lend themselves to an integrated operation much better than those that we have in other watersheds.

These properties consist of over 140,000 acres of forested land. This land is primarily covered with a mixed softwood growth varying in size from the seedling to mature trees thirty inches or more in diameter.

All of this land has been cruised within the last six years, volumes by species computed, type maps and a management plan made. There is approximately three times as much Spruce and Fir by merchantable volume as there is Pine. Some of the areas are served by a good truck road system while other areas are quite remote from truck roads at the present time. As there are some softwood species which cannot be water driven successfully, I consider truck roads to be very important to an integrated operation.

The Machias River is drivable for long logs from the northern boundaries of our land to Whitneyville, a distance of approximately sixty miles by the river. As many of you know, the Machias has been driven for nearly two hundred years and is well equipped with dams for water storage, abutments, piers and log booms.

We have at Whitneyville a permanent sawmill, a dry kiln for lumber, a drumbarker for four-foot pulpwood, railroad sidings serving both the sawmill and the barker, as well as all of the service buildings necessary for a sizable woods operation.

In addition we have a pulp and paper mill at Bucksport, which is 107 miles by rail from Whitneyville. This mill requires mostly Spruce and Fir, and is equipped to use four-foot wood. We have recently operated a small kraft pulp mill which used a large percentage of Pine. This latter mill is not in operation at the present time. We also have a large truck fleet of our own.

So much for the physical properties. I do consider them, though, to be most important, if one is to conduct a successful integrated logging operation. We will now turn to the woods operations.

We have tried to cut four-foot wood and long logs on the same operation and at the same time, but for many reasons, soon gave up the idea. Generally speaking, a four-foot operation requires different equipment, road layout, and river landings than a long-log job. The lumberjack cannot always be depended on to follow instructions as to which trees are to go into pulpwood and which ones are to be made into logs. Piecework wage rates are difficult to set and to handle on a mixed operation. A good man is not interested in working by the hour.

Our real integrated operations cut Spruce, Fir, White Pine and Norway Pine logs mostly in twelve and sixteen foot lengths. There are a very few eight and fourteen foot logs cut.

Slashing to length may be done at the stump if the log is too large to be horse skidded, at a yard on a hauling road if the logs are to be cold decked, or at a river landing if the terrain and ground conditions will permit them to be skidded with a sled or a truck-drawn sulky. These logs are driven to the mill at Whitneyville during the Spring freshets.

Some timbered areas that we have cut and others that we plan to cut have good stands of Norway Pine best suited for piling or utility poles. These are cut to the best advantage for us and to meet the specifications of the company buying them. Because of the difficulties in driving long Norway poles, they are trucked to Whitneyville, where they are loaded onto railroad cars.

Hemlock logs do not drive well because of their heavy weight. Most of the Hemlock that we have in the Machias valley is sap-peeled during the regular season and made into four-foot pulpwood, which can be either trucked or river driven.

After the river driven logs reach Whitneyville, they are sent to the sawmill where they are either sawn into lumber or slashed into pulpwood, in whole or in part. We have no inflexible rules that for all time determine which logs are to be sawn into lumber or are to be slashed into pulpwood.

A few years ago all of the better Spruce logs were sawn into lumber. Changing conditions made it impractical to continue with this plan as the dollar return on the lumber was not sufficient to buy a like volume of Spruce pulpwood from other sources for use at the paper mill. Later it developed that we could use the lower quality Pine, to good advantage, as pulpwood for the kraft mill. This phase has passed and now we are sawing all of the pine harvested into lumber.

We feel that we are making steady progress toward running integrated operations in the Machias area, as well as in one or two other areas where we have large acreages. These integrated operations are made possible by a sound program of timberland management which we believe will result in a cutting cycle of about 25 years. By following this program, we should have a permanent supply of logs.

To sum up what I have said: I believe that certain conditions have got to exist to conduct integrated log operations profitably. These are:

1. Sufficient timber in one general area to yield a fairly large volume of each kind of logs.
2. Generally all of the logs have got to be concentrated in one place before final sorting; otherwise, handling costs would be prohibitive.
3. A plant to process the logs into other products or a market for them within economical hauling distances.
4. An alertness to changing market conditions.

[1] Presented at meeting of the Forest Products Research Society, Northeast Section, May 7–8, 1951 at Portland, Me.

Selling Lumber and Lumber Products[1]

JOHN RENO

Utilization Director, The Pacific Lumber Co., 35 E. Wacker Drive, Chicago, Ill.

Author describes how his company stresses service to the dealer and ultimate consumer as means of building and maintaining high rate of sales. Aim is to help customer get best possible job from lumber he buys. Much of this work is based on research to assure that lumber and lumber fabricated products are properly manufactured and designed. Development of markets for shorts, bark and other by-products frequently considered to be waste is also described.

MANY TIMES THE QUESTION has been asked "How has The Pacific Lumber Company maintained a constantly oversold condition for many years even during those periods of economic dips when other good lumber manufacturers found it necessary to drastically curtail production or face uncomfortable inventory surpluses."

In this paper I am going to talk about some of the means by which this lumber company, regularly producing over a half million feet of lumber per day, does manage to get the orders necessary to absorb its production.

We manufacture and sell rough lumber, surfaced lumber, paneling, siding, mouldings, pickets, edge-glued cores, end-glued pieces and lumber run to patterns.

This paper is not intended to be promotional, but I have to start out by saying that the first requirement in our sales program is that our product must be as nearly perfect as our mill can make it . . . and this near perfection must be maintained day in and day out. The knowledge that this is so gives our sales force the self assurance that is so helpful in selling. Our selling prices are firm and are reasonably related to our costs—not to the prices of our competitors, distressed or otherwise. Sometimes we have price differentials to combat, and it is at these times that our salesmen have to be sure of themselves and of their product.

Of course, this method of pricing creates a lot of good will, especially when lumber is hard to get. For instance, after the demise of OPA at the close of World War II, there was a definite seller's market and many lumber manufacturers took advantage of the situation to raise their prices to the fullest extent the market would allow. We continued to quote steady and reasonable prices and, on many items, we were as much as a third below the market. The good will this created has not hurt us any.

Getting back to normal selling conditions, the next step after we, ourselves, are sure of the quality of our product is to convince the prospective customer of this fact.

We go about this in a number of ways.

Of course we do a certain amount of regular advertising in trade papers, etc., but our maximum effort is of a more personal nature.

For instance, we cooperated fully with The Saturday Evening Post when they indicated a desire to write a feature story about our mill and our company-owned town of Scotia, California, in which the mill is located. One of their writers lived at our inn for a period of time, gathering material for his manuscript which later appeared in The Post under the title of "Paradise With a Waiting List." We distributed many reprints of this article.

The same cooperation was extended to The Wall Street Journal and subsequently an article entitled "Lumberjack's Utopia" appeared on the front page of that paper. Again reprints were distributed.

By implication, at least, The Saturday Evening Post and The Wall Street Journal gave the stamp of approval to our product.

We are aware that any manufacturer can claim that his product is best—and many do! Accordingly, when we make such a claim, we attempt to tell in detail in an interesting manner why we think our claim has merit.

To keep such information always before the prospect requires that it be in writing. Not dry statistics but in a story that is convincing, alive and interesting, as well as truthful and factual.

Many hours of hard work were put into the job and finally out of this effort came the article "Sawmilling at Its Best" which appeared in "The Southern Lumberman." In response to demands, over fifty thousand reprints of this account of how we make our lumber were distributed to the trade

Ralph J. Simeone, sales manager, J. J. Fitzpatrick Lumber Co., Madison, Wis., wholesalers, explains to Madison dealer Pat McCormick, McCormick Lumber and Fuel Co., how customers can frequently get right size cuttings from shop grade redwood, in place of buying higher priced redwood clears. Dealer can also make pickets and other items for the homeowner from shop cuttings.

[1] Presented at meeting of the Forest Products Research Society, Midwest Section, July 23–24, 1953, at Madison, Wis.

Expertly manufactured lumber items that live up to grade specifications in every respect build customer confidence and bring repeat orders.

. . . and this distribution is still going on.

However, our writings are not confined to telling how good we are.

As a matter of fact, most of our articles tell our customers and also the ultimate users of our products how to get the best results from the utilization of our lumber.

For example, "Paint Troubles on Redwood Siding—Causes and Cures" which first appeared in "American Lumberman" faced a problem and gave the solution. Demand for reprints again numbers into the many thousands. Even manufacturers of cedar siding have distributed this one as the problems involved apply to siding of any species of wood.

An article entitled "Buying Lumber for the Factory" appeared in more than two dozen purchasing agent magazines from coast to coast. It received wide acceptance because it was a practical lesson on how to buy lumber intelligently; on how to avoid costly mistakes in buying.

Many other manuscripts have appeared or will appear under such titles as "Screw Holding Properties of Redwood", "Redwood Core Stock", "Recognizing Assets", "Natural Finishes for Redwood Siding", "Wood vs. Aluminum—Keeping Homes Winter Warm and Summer Cool" and "Getting Humidity Out of the Home", etc.

Of all the articles that we, ourselves, prepared, only "Sawmilling At Its Best" included promotional material for The Pacific Lumber Company. None of the rest of them contains any promotion for our company. Some do not even mention Redwood. They all are full of practical "helps" for the lumber dealer, the builder, and the home owner. However, every one of them carries our name as the author which clearly indicates two things to the reader.—

1. We are trying to be helpful to him.
2. We know our business—he can depend on us!

The ever-present reprints are always available.

In addition to frequentiy putting something useful in writing for our customers, present and future, to read, we constantly are carrying the message to them by word of mouth.

We make talks all over the nation before chapters of the American Institute of Architects, Home Builders Associations, Lumber Dealers Associations, classes of the thirty-day college courses on Lumber Merchandising etc.

The title of the talk is the same to all—"The Proper Use of Lumber in Building—Especially Redwood." There is very little in the way of promotion in the talk but, instead, it is full of "helps."

It will be hard for you to believe it, but the formal talk takes about one hour and forty-five minutes to two hours, and all of the groups mentioned above sit still for it and even stay for another half hour or so of a question and answer period. This is because we are giving them information which they want—not promotion.

It might surprise you to know that we tell all of our audiences that the production of Redwood is relatively limited and that Redwood should be used only where it is needed—where it will do a better job!

Again, although the talk is not promotional, everybody present knows it is The Pacific Lumber Company that is bringing this valuable information; and that it is The Pacific Lumber Company on whom they can lean for technical help—and to whom they can turn for lumber.

In our talks to lumber dealers we impress on them that our sales stay high because we constantly are trying to be of service to the customer—to help him use our lumber to his advantage or profit.

We recommend that the dealer use the same approach.

A customer has a question on lumber, building or design—answer it!

A customer has a problem about lumber, building or design—solve it!

Do something definite and tangible for the customer each time you call on him or he calls on you.

Pretty soon the customer gets to thinking that the dealer is a pretty valuable man to him, and he cannot always be getting help from the dealer without buying a good part of his lumber from him.

Of course, in order to help the customer, the dealer must know the answers himself. We try to give the dealer the answers.

As further assistance to the dealer, we call on his customers with him when he needs technical or sales help. You will notice that, in addition to selling lumber, we provide assistance toward the profitable use of that lumber by our customer and even by our customer's customers.

On the premise that anything that helps the Redwood Industry helps The Pacific Lumber Company, we often suggest projects to the California Redwood Association.

For instance, although Redwood is known as the easiest of woods to glue, we thought it would be good promotion and helpful to our customers to distribute an Association release on "The Gluing of Redwood." As far as we know, no other species sponsors such a booklet. The California Redwood Association carried the ball and even spent the money to set up a project at the Forest Products Laboratory to get new information on the subject, if possible.

Similar procedure resulted in the CRA publication . . "The Machining of Redwood." These are just two of many technical and sales promotion releases of the CRA, almost all of which were initiated and carried through to a successful conclusion by their own Association personnel.

The same resolution "To be sure before selling" caused The Pacific Lumber Company to place a research program into the hands of the Forest Products Laboratory before putting their electronically edge-glued Redwood core on the market.

All known technical data indicated that Redwood would make a fine core for high class furniture panels, but

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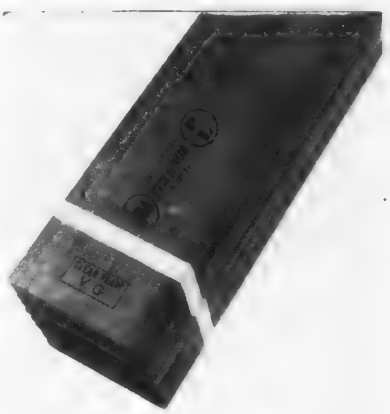

Lumber items requiring further manufacturing, such as this electronically edge-glued panel, is thoroughly tested for satisfactory performance before marketing, thus eliminating customer complaints before they arise.

Trends In House Construction[1]

J. C. TAYLOR, JR.
President, American Houses, Inc., New York, N. Y.

Author sees first aim in future housing as development of a material or combination of materials light and strong enough so that entire wall panels can be built in one unit, with floor panels eight feet by thirty-two. To achieve these aims panel weignt must be held to four pounds per square foot. Such a house would require development of basic materials, connector methods and new mechanical equipment. The author looks to moulded plastics (even studs) and bagasse as sources for new basic material. It might further be pointed out that light-weight wood sandwich panels currently in the development stage offer possible solutions to the weight-strength problem also.

I AM ENGAGED in the house building industry, particularly in the field of prefabrication. I have lived with the problems and achievements of this industry for 15 years. Out of these years have come for me, certain conclusions, and one of these is: our engineers have played far too small a part in the home building industry, and as a result the industry is behind the place where it should be today.

Who is to blame for this condition or what set of circumstances brought it about, I do not know, but today I want to try to arouse an increasing interest on your part; I want to tell you what some of us in the industry have as goals; I want to point out what I consider the "house of tomorrow" can be from a construction standpoint and thus show why we need the skill, the talents, the imagination and efforts of engineers all over the country.

First, I want to say that the building of homes constitutes the greatest potential market in the world. No line of endeavor compares with it in potential volume. A member of the Indonesian Congress was in my office last month and said, "On the Island of Java alone they are in desperate need of two million homes today." South America, Africa, Europe, Asia, every part of the world is in need of homes, in fact, the number of millions needed almost staggers the imagination. This need is measured to what is to us a very substantial level. Most countries think in terms of one room for from two or three people, against an American standard of from one and one-half to two rooms per person.

Converting such a need to an actual market is, of course, the problem, but in no similar commercial challenge in history has there been so much favorable pressure:

1. Housing, aside from war, is the Number One political issue all over the world. Leaders in democracies, tyrants, kings, revolutionists and reformers all promise housing to the people because it is good politics. Most of them are serious too, because they feel that this is a promise that they must make good.
2. No phase of economic activity except production for war gets so much Government aid on a world-wide basis as housing.
3. Real reformers, our churches, our social workers on a world-wide basis agree that in adequate housing lies the greatest single factor in any nation's security and in its real participation in a free world.

Our picture here is different in many respects, but still is a great challenge. No one knows the extent of the market for homes on farms if they could be built at reasonable cost. The vacation cottage or summer home factor is very large. Millions of families need a larger home with more rooms. The impact of television on our living has been great, and one of the results is that people stay at home more. They need more room. The decentralization of industry is taking place and will continue. Ahead of us we have a great and real problem in connection with housing the aged and the retired. On top of all these factors is a normal compliment of from 700 to 800 thousand new homes needed annually as a result of obsolescence, fire and storm, and new family formation. This is but a brief picture of housing need as its exists today.

In discussing housing and the problems connected with it on a world-wide basis, I would like to skip over the factor of war, either hot or cold, because sooner or later by some means our world must and will settle down to peace.

One of the greatest handicaps in most countries is lack of suitable materials out of which houses can be built economically. South America for example, has much lumber but only a fractional part of it is suited for housing. Masonry in the form of adobe, cement or brick is available in most countries, but it is expensive in terms of money and in terms of manpower. It is heavy and in most instances transportation facilities are not adequate. The construction period is much too long if the program of housing is to be solved. When you talk of building houses under such conditions, you are speaking of a product that will be available to the wealthy few. In Israel, Greece, Brazil, India, Cuba, Indonesia and many other countries the cost of homes built today transformed into the wages of the average worker represents as much as 10 years of gross income. In our country we think in terms of two and one-half times the gross income for a year as a reasonable price for a home, and yet here costs are too high to meet the demand in many classifications.

Weight Factor

Weight is another very important retarding factor. It is so important because transportation is a real factor in cost. It has been estimated that in a 4-room house built in this country of a 700 to 720 square foot area, there is involved approximately 21 thousand ton miles of transportation.

The customary way to build a house is to put it together from many small pieces. Prefabrication, using panel construction, has improved this condition a great deal, but we must go even further and use larger and larger panels; in fact, building the whole side of a house in one piece before the house is shipped to the site is desirable. Such a panel with today's construction calls for mechanical equipment for handling and erection at the site, and this is impractical except for relatively large projects.

[1] Presented at meeting of the Forest Products Research Society, Northeast Section, December 4–5, at New York City.

This and many other disadvantages of present day construction led me to conclude some time ago that our present types of construction are inadequate, because using them we cannot fill all of the existing demand at home, and in them we have found relatively no solutions to the greater problems existing abroad.

I want to describe a method of building a house and present to you one possible way of overcoming a large part of the "road blocks" which we find in our paths. Aside from the foundation, a house is made up of five main parts plus mechanical equipment for heating, lighting, plumbing and, in some instances, air conditioning. The five parts are: floor, exterior walls with openings, interior partitions with openings, ceiling and roof. The function of each of these five parts is well known. The required characteristics as to strength, rigidity, resistance to weather, etc., are all a matter of record. Testing procedures have been well established. We know what we need and we know how to find out when we have it. We know the cost of each of these parts broken down into materials, labor, transportation and financing. In short, we know what we have to work with pricewise.

Highway Shipments

We know that we can ship by truck over our highways panels 32 feet long by 8 feet wide. Therefore, we should have in a 24 x 32 foot house only three floor panels 8 feet by 32 feet. These panels must be complete with finish surface, insulation, sufficient strength and rigidity to meet all floor requirements for housing, and placed at an 8 foot span. The weight must not be more than 4 lbs. per square foot.

For our exterior walls a similar material or composition of materials out of which, in a factory, can be assembled full wall sections, with windows and doors and insulation up to 32 feet in length and up to 8 feet in height, and weighing not over 3 lbs. per square foot. The same idea for partitions, with the weight not exceeding 2 lbs, per square foot, ceilings not more than 2 lbs., and roofs from 3 to 3½ lbs. Using such material we would enclose a house with 3 floor panels, 4 side walls, 2 gables and not more than 4 roof sections, a total of 13 pieces, each of which could be unloaded and erected by hand labor at the site.

In my opinion this is our Number One goal. The trend in architecture is toward straight lines and flat surfaces You can call it modern or contemporary or what you will. Interiors are becoming more and more simple. The extensive use of glass is the order of the day, and such embellishments as dormer windows are fast disappearing. Such a material or composition of materials as I describe will fit in beautifully with current architectural trends. Transportation costs would be at a minimum; field erection as to time and cost would be at a minimum, in fact, if your foundation were ready, building a home would be a matter of a few days at most, for each erected part would be completely finished except for the final coat of paint, in case the material used needed painting.

One of the most expensive items in houses today is the equipment for heating, lighting, plumbing etc. Even in our prefabricated houses these jobs are done by subcontractors in the same manner as they are done for conventionally built homes. Once we have worked out our goal of building the house enclosure as we think it should be built, the improvement in the mechanically-operated gadgets will follow. Our panels will be shipped wired, cutting for the trades will be done, and all the equipment will be shipped for rapid installation even as automobiles are now shipped to dealers minus items such as clocks, horns, seat covers and in some cases, batteries. Such a house will be one that a farmer and his sons could well build themselves in a few days.

In evidence throughout such a development must be the engineer to develop basic material, work out connectors, develop new mechanical equipment and a thousand and one requisites.

Does this sound like a dream? I want to recall for you what happened during the early days of the automobile. In the first go-around, the emphasis was on power. The first cars were buggies with an engine mounted instead of a horse hitched. For years the experiments went on, steam power, electrical power, gasoline power, chain drives, belt drives, etc., and eventually the power plant was decided upon. When the power program was solved the other developments came one by one. The industry developed a completely new conception of transportation until today your car has everything, a radio, its own heating plant, its own electric lighting plant and, in some cases, air conditioning. This same kind of development is going to take place in housing, and the house of the future from the standpoint of design and cost will no more resemble present day houses than the automobile seats in your car resemble the buggy seats of 1900. This is the challenge and the question is: Are you and I going to take part, are we going to share in the achievement?

I promised to mention one way that a panel such as I describe might be produced. When and as it is produced, I think it will be of laminated or so-called sandwich variety. An exterior wall, for example, will be made of two sheets of material, one providing interior finish and the other the exterior finish. Between the two, reinforcing or strength giving materials of the moulded plastic variety and, possibly, a plastic stud in place of a wood member. The inner and outer surfaces glued to the plastic member. Experiments along this line are very encouraging. Many of the present sheet materials, such as hardboards, offer great promise, and if they fall short I believe that improvements in their manufacture can be expected. Experiments in floor panels along the same line are encouraging also.

Local Assembly

Such a panel offers much through the medium of local assemblies. The reinforcing members can be moulded at one central point in the country, shipped to various assembly plants where they would be, along with windows, doors and sheet materials, etc., assembled into full wall sections. Such construction could be carried out in almost any country in the world. Even if certain materials had to be imported, they would form little bulk and make up only a fraction of the total cost. The world is full of raw materials for the manufacture of sheet materials needed, in fact, if necessary, these materials can be grown as a crop. Think of the bagasse that is burned or wasted each year.

I hope that you do not think that I believe the job is a simple one or that the answer is just around the corner. Time, much time, will be used. Many, many hundreds of thousands of dollars will be spent. Talent, the finest we can find, must be used, and that is where our engineers come in. Without their faith and help and vision, the job cannot be done. It has been said that when you can define your problem you have it 75% licked. I think that applies to this problem and I believe that the answer will be found.

In discussing housing, I considered the world as a scene. I believe that is the correct approach. Whether we like it or not, we are now an integral part of the world, a part of a confederation of nations. Our country has much to offer in helping to improve world housing.

Economic Aspects of Residue Utilization: A Few Basic Questions Examined[1]

EDWARD D. GRUEN

Assistant Professor of Finance and Statistics, Amos Tuck School of Business Administration, Dartmouth College, Hanover, N. H.

Discusses residual utilization from various viewpoints: first, the various possible divergent goals of professional groups who have contributed technical guidance; second, basic motives that might induce the public to support a long-range program for putting more wood waste to use; and third, the economic conditions necessary for broadening use of wood waste. In the latter case, the author points out various factors that may work for increased use of wood residues even while the per capita consumption of lumber is expected to continue falling.

Introduction

THE YEAR 1947 MARKS an important milestone, perhaps even a significant turning-point, in the history of forest products utilization. In that year this Society was founded and the U.S. Forest Service published the first nation-wide survey of wood waste (Report 4, The Reappraisal of the Forest Situation). The co-author of this report, Mr. Robert K. Winters, presented a paper at the national meeting of F.P.R.S. the following spring on The Importance of Economic Considerations in Wood-Waste Utilization Research. In this paper he called for "a generous amount of clear economic thinking by the chemist, engineer or other specialist at the time waste-utilization studies are being planned and carried out . . . to permit concentration of effort on those likely to develop processes that can be useful in plant operation as well as in wood-waste utilization."

Mr. Winters' call did not fall on deaf ears. During these five years the pulp and paper industry has developed or perfected several major new processes which use as base stock either round wood of (formerly) noncommercial species or chips prepared from wood leftovers. Included here are the neutral semi-chemical sulphite processes employing Northern and Eastern hardwoods, the new sulphate process for making dissolving pulps from Southern hardwoods[1] and the bleached kraft pulps which are now made in the Pacific Northwest with chips from logging, sawmill and veneer mill residues.[2] The post-war introduction of efficient processes for using waste in hardboard[3] and insulating board[4] making should also be noted.

A number of other innovations could be cited—the use of mill waste as a filler in plastics, as core stock in plywood panels, as cut stock in furniture and other factory products, in laminates, and so on. There is no denying the pleasure afforded by the opportunity to take an inventory during a period of progress. But such a period also makes an ideal time for the "kibitzer" to raise a few questions! For example, there might be some profit in knowing which professional group (or groups) supplied most of the technical guidance. Then there is the matter of goals and, fully as important, the prime motives behind the present campaign to "Make Haste with Waste"—can these be identified? And what about the term "waste" itself—can there be a static concept of it? Finally, what are some of the factors favorable to (and unfavorable to) more intensive utilization of wood—and which way does the balance seem to be tipped for the future?

Residue Utilization—Whose Field Is It?

We are accustomed to hear in this day of the specialist that technology is moving so fast the owner or manager of a business, let alone the mere layman, is ill-equipped to act or even judge, unaided. To whom, then, has industry turned for expert advice in residue utilization—the engineer? the chemist? the forester? the economist? the research director? In the files of this Society alone, we should find all the evidence we need for an answer to this question. (Author's note: to rule this type of evidence inadmissible would require a demonstration that the progress made by industry the past five years and the coincident maturing of the F.P.R.S. as a research forum were wholly unrelated events—something only the brashest novice in the field would ever attempt to prove!) Let me show you a small controlled sample ($n = 5$) drawn from a single day's reading of F.P.R.S. publications under, as they say, standard conditions—

> ". . . the diversification of the raw material sources of hardboard production indicates an important trend. It shows that hardboard and similar base products can and will utilize increasingly important amounts of the byproducts of the forest products industry that at the present time find no better use than as hogged fuel. . . ."

This first item in our draw represents a credit to the *engineer*. It came from a paper on the Hardboard Industry which Wayne Lewis of the Forest Products Laboratory (Madison) presented in Raleigh, N.C. last November.[5]

> ". . . The utilization of wood waste cannot be considered an end in itself, since the inefficient use of capital and labor resources is worse than the loss of a potentially valuable material. . . Chemical uses where the fiber is destroyed should be a last resort. . . ."

Surely this is the economist speaking—or possibly a lumber technician? No, this is the counsel of a chemist, Jerome F. Saeman (also on the FPL staff at Madison), and it was given at the national meeting last June.[6]

> ". . . About the turn of the century the motivating influence (in forest products utilization research) was to conserve the forests; today we study wise and efficient use of wood to conserve manpower and capital and to promote more intensive management of the forest . . .

This appraisal does not come from anyone with a private interest to serve; instead it represents the considered

[1] Presented at meeting of the Forest Products Research Society, Northeast Section, May 7–8, 1953, at Portland, Me.

[2] The author is making a study of this subject, oriented to New England with the aid of research grants from the Federal Reserve Bank of Boston.

judgment of Lyle F. Watts in his capacity as Chief Forester of the United States. The passage appears in the paper Mr. Watts prepared for the Society's 1952 national meeting.[7]

> ". . . The pulp and paper industry has been built to its present size largely upon waste or scavenger materials. . . . Paper can use the cellulose fibers from any leafy green plant (but) both for cost and technical advantages, it has turned to wood discarded as unmanufacturable by sawmills and other timber users . . . . . ."

Does this author's professional training give him away? He may have sounded like a chemist or laboratory specialist, but actually this is an excerpt from a paper given by an economist, Louis Stevenson, who retired quite recently after long service with the American Paper & Pulp Association.[8]

> ". . . In recent years the developments in logging, transportation and manufacturing methods coupled with the enactment of state forest laws have encouraged close utilization in the Pacific Northwest . . . (and) have changed the thinking of men responsible for planning woods operations."[9]

Our last quotation, appropriately enough, is as broad as the field and befits the man who serves Simpson Logging (Shelton, Washington) as Vice-President in Charge of *Research and Forestry*—Mr. George L. Drake, whose professional colleagues paid their tribute last year by electing him to the Presidency of the Society of American Foresters.

To my way of thinking these citations illustrate that no single professional group can stake out an exclusive, or even a prior, claim to the field of residue utilization. Each has an important contribution to make. Indeed, had the specialists dissipated their energies in petty quarrels over rights and prerogatives, it is most unlikely that the utilization record would have shown any major advances. This is not to say that it is an easy matter today to arrange for an effective pooling of specialized information on a given subject preparatory to making policy decisions. Far from it. With the trend toward more compartmentalization of knowledge still running strong, a professional society such as this probably has all it can do to induce the members immediately concerned to enter into a direct exchange of ideas and tentative findings.

Choice of Ends—and Means

With the field being shared by so many groups, a possible complication is introduced, however: suppose the goals of the various technical (staff) groups don't coincide? Or, granted that they may appear to set forth the objective in common—or at least reconcilable—terms, may they not be found to differ seriously on the means for achieving it?

Forester's Viewpoint

If we may take the recent Report of the Governor's Forest Policy Committee (for New Hampshire)[10] as representative of the forester's outlook—and from my personal acquaintance with the drafting of that report, I think we may—then the *forester* can be said to view utilization as one means (better cutting practices being the other) for bridging the present gap between drain and growth in softwood sawtimber. The Summary issued by this Committee leaves no doubt that the over-riding objective, to use their words, "is to build up enough desirable growing stock to assure adequate future production . . . (and that) the key to this problem lies in better cutting practices and improved utilization." The appraisal of the New Hampshire forest situation, which formed the basis for this policy declaration, was in familiar terms: "Most of the state's forest area is in poor condition. . . Softwood sawtimber is being cut faster than it is growing; low-grade hardwood is growing faster than it is being used." With this approach the forester has taken a hand in developing markets for weed trees, culls and inferior species—the more thinnings and improvement cuttings that are made, the closer is brought the day when our commercial forest land will be at optimum productivity. His interest in the wider use of mill residues is not quite as direct: here the chief appeal seems to rest in the prospect that forest-based industries will thereby be assisted "in making the transition to using continuous forest crops."[10]

It is not for the others to think in these terms. To the *chemist* a tree is a wondrous living factory (to apply Donald Hardenbrook's simile [11]) creating without the aid of man cellulose, lignin and hemi-celluloses, not to mention a variety of complex compounds in the form of tannins, tars, gums and oils. For cellulose, "the noble molecule", he has the highest regard; for lignin, whose properties remain elusive, the greatest curiosity. A good illustration of the difference in approach is furnished by the high alpha dissolving pulps. The chemical industry has long since confirmed their rank as an important industrial raw material. Engineers are impressed not only by their high output/input ratios on production lines, but also by the sheer efficiency of the forest in growing as much cellulose fiber annually on one acre as the yearly harvest from five acres of good cotton land.[11] And the economist, who by training looks to the amount of dollar value added to raw wood when he compares one wood use to another, reaches the same conclusion. That is to say, the conversion of wood to purified cellulose is as commendable in the economist's eyes for the five-times multiple in value which occurs through processing to this form as it is to the chemist for its stable character in reactions, or to the engineer for its high efficiency in physical volumes yielded. (Harold Shepard's recent article on the New England Pulp and Paper Industry[12] presents data which seem to me to support such an inference as to the economist's view.)

Various Aims

The important point we come to from all this is that we have here the basis for a potential conflict between the specialists over ends as well as means. Chemists, engineers and economists are inclined to think—if I may up-end the old saying—that "foresters often fail to see the wood for the forest." To non-foresters the fact that dissolving pulps (to stay with our example) can today be made from wood generally considered inferior or even 'unmerchantable', is largely incidental. To foresters, though, this very fact is all but determining. In other words, had these stands of timber been judged capable of producing continuously an adequate volume of sawlogs, then the support given by foresters to their diversion to pulp—would probably be found to range from cool to nil.

That this division of opinion should arise is natural enough—after all, the forester is the only one of these specialists whose training and, indeed, his subject itself require that he take a generalized view of the forest and learn to think in terms of generations. What does concern us, though—and to my mind it justifies our raising the question when we examine the forces at work in the field of residue utilization—is whether the forester is likely to insist, when the chips are down, that the tests of the laboratory and the market place must give way to his concepts of what makes for sound forestry in any long-run management of timber resources. Admittedly, this is an area where little can be known for

certain, but, if we are to get any measure of it, we must at least probe deep enough to identify the motives that impel the various groups to "Make Haste With Waste."

"More Haste with Less Waste" . . . Why?

At first glance it must seem pointless merely to raise such a question at a technical meeting of this kind. Aren't we all against waste just as staunchly as we're "Agin" sin, war, high taxes, inflation and—to bring it closer to home—forest fires? Of course we are, but how many are with us and what are their reasons? . . . In a word, will they stick to the finish? The more one observes the slow progress man has made in attacking the evils of war and inflation—to mention two most everyone today says he recognizes as evil—the more convinced one becomes of the necessity for discovering WHY people oppose (support) any given program. It could happen, in our case, that we too may find—"when the chips are down"—that the popular protest against waste in the forest industries is poorly-rooted and programs designed to combat it are, therefore, not likely to receive strong and dependable support. Or it could be that our support is solidly grounded in "a growing awareness of the potential value of the wood substance now being turned to waste." The quotation is from J. H. Jenkins' excellent review of the status of wood waste utilization in Canada just published in Ottawa[13]; he goes on to cite this development as "perhaps the most significant (one) in the continuing search for a more complete and effective utilization of trees from our forests."

At the very start differences crop up when we try to settle upon a satisfactory definition of the term "wood waste." But these are minor and probably disturb those who compile and use the statistics more than they do you, so we can pass over them rather quickly. Most definitions are in descriptive terms and the common practice in technical literature has been to follow rather closely the example set by the U. S. Forest Service and Mr. Winters in the reports cited in the opening paragraph of this paper. This means, briefly, taking as "waste" all wood incident to the harvesting and processing of the original tree which does not enter into the primary product. Accordingly, this definition includes the so-called logging or woods waste (tops, branches, slash, injured trees, etc.) together with the mill or plant waste which develops from primary and secondary manufacturing of round wood and lumber (slabs, edgings, trim, sawdust, shavings, etc. at sawmills; veneer cores; lignin and cellulose lost in pulping; etc.). Bark is usually not counted as wood—this treatment must sound strange in the Douglas Fir region in the light of their recent promotions. (Parenthetically, any reference to bark in Maine could stir up memories of the days when cattle hides—as I have been told—were brought to the forest, to tanneries set up "under a spreading chestnut tree", so to speak; then the bark was the thing and the wood was often just a nuisance!)

Many feel that, ideally, the concept of "what is left over" should be extended to include unsevered wood such as the inferior species, weed trees and other growth in surplus for want of a market that will pay for their removal from the forest. But as it is, field surveys generally have to settle for narrower definitions. For example, the Jenkins study of Canadian developments in waste utilization cut off at primary manufacturing, (and even there excluded pulp residues) and the inventory of New England wood waste, the results of which were published in 1949[14], was confined to manufacturing waste from lumber and turnery operations, with logging as well as pulp mill residues excluded. Wherever we draw the line, waste can, of course, be only a relative term. Wood which is discarded at one place, or at onepoint in time, as economically impracticable to use may, at other places or times, be considered prime material. Moreover, the quantity of waste produced in processing is directly related to the end-products of the conversion processes, hence is subject to change as the markets and technology change. What really matters, it seems to me, is that the forest industries continually conceive of these residues as by-products, in much the way they are treated in the chemical and petroleum industries. When this more dynamic approach is linked up with aggressive research and willingness to venture, then the day will come when we can say that unutilized wood residues are today's by-products for which we will find an economic use tomorrow.

How to Prompt Support

Now to turn to the motives that may prompt the American people to give unwavering support to a program aimed at eliminating "waste" in the forest industries. First of all, it is wholly out of keeping with the facts to say that we are a people who are allergic to waste in any form. That may have been true in Colonial times, but the opening of the West seems to have put an end to it. Nor can it be seriously maintained that, with the benefit of a century of hindsight, we now look back upon the pace of our development as an industrial nation and find that our progress was impeded because of the prodigal waste that accompanied it. One does not have to accept all of Professor Galbraith's thesis[15] to conclude that the rise in our material standard of living would indeed have been much slower, had we not concentrated most of our efforts on the job of catching up with Europe in the shortest possible time—and, one must add quickly, had we not been so generously endowed with natural resources for ready exploitation!

No, we must look elsewhere for the underlying reasons. Could it be that fear of a lumber famine for future generations has once again taken hold and that this accounts for the growing awareness of the need for using all of the tree? This scare technique has worked in the past—to influence forestry practices as well as the course of the conservation movement. For an expert opinion, I take you to Montreal last November at the time of the first joint meeting of the Society of American Foresters and the Canadian Institute of Forestry—and I quote from the theme address by Mr. R. A. Bentley on Trends in North American Forestry:

> "The greatest change in utilization in the past fifty years has been the change in the position of the different species in their value and use. In the lumber days only a few species were used, and as these became scarce the predictions of timber famine came up periodically. Each time the conservationists have been confounded by industry switching over to other species previously considered weeds. As the softwood species are now predicted to be approaching exhaustion, industry plays the same trick again, before the shouts of disaster have really got started in full cry . . . Any increase in the future use of wood as lumber has a dim outlook, but the pulp products will consume constantly increasing volumes produced at lower costs. The quality of hardwoods for these purposes . . . opens up a whole new field of utilization."[16]

A brief discussion of the outlook for lumber will be given shortly. Here I should only like to add this to Mr. Bentley's comments: those of us who think mostly in terms of the forest tend to miss the implications in our argument to the public that timber is one fundamental source of materials which is renewable. Note that this is

being said to a generation which needed the immense demands of a second world war to be aroused by fears that its exhaustible resources might soon play out! And now what do we find happening? In the few years since 1946, when fears of an impending shortage of strategic metals and minerals—including petroleum—ran strong, an attitude close to complacency is once again asserting itself. And this can not be dismissed as sheer recklessness on the part of an uninformed public. The prediction that our high-grade iron ore reserves in the Mesabi Range would be exhausted in 14 years was authentic enough (and certainly well-publicized), but the discovery of new high-grade ore deposits in areas as widely separated as Labrador and Venezuela, coupled with an unexpectedly rapid development of economic methods for beneficiating our own low-grade deposits, have changed the outlook almost overnight. Thus it appears that the "Mesabi Ghost" is laid to rest for another generation. Under these conditions, it strikes me that we would be just "shouting in the wind" to plead for widespread support of a use-wood-waste program on the ground that in no other way can our children be assured the timber and lumber they need.

The Economic Case for Using More Waste

Fortunately, the case for more intensive utilization of wood rests upon a much firmer base. There are a number of good economic reasons why wood residues are coming more and more to be treated by industry as important raw materials in their own right—and these will be identified in the next and final section of this paper. Owners and managers of established forest industries may well feel that their investment gives them reason enough to use these by-products, wherever practicable, to stretch out their raw wood supply—and so at this point they may be inclined to ask: What else do we need to know? What else can be of any concern to us as operators?

To my way of thinking, we still need to know what the general public will make of the economic case for intensifying the search for new products and new processes employing wood waste. And we should be concerned about whether these arguments are strong enough—that is, provide the basic motivation required in support of an all-out attack on "the wood waste problem." We have seen that neither a general aversion to waste nor the fear of a lumber shortage were strong enough to be depended upon. (Implicit in this whole line of reasoning, of course is the conviction that public opinion in this country is a powerful agent—for good or evil.) The bid for support on economic grounds can be made in the following terms:

(1) The greater use of wood residues would have the effect of bringing down the prices of primary products — either through direct competition of substitutes made from the by-products, or through processors and stumpage owners passing on some of the benefits in order to expand their markets.

(2) The greater use of wood residues would have the effect of creating more wealth and useful employment—through expansion of the total production of goods and through more intensive management of the forest — without increasing the commodity drain on the forest.

There probably is little doubt that, given a choice, the forest industries as a whole would elect for proposition (2). The first statement does seem to ask the lumber industry (to name the largest party at interest) to go into competition with itself and reduce its own prices in the bargain. But there actually is no open choice in the matter and (1) as stated would not seem unreasonable to consumers and the general public. Certainly not at a time when many lumber items are selling at prices three times what they were before the war, and not so long as there is the slightest reason for believing that a part of the high price of lumber goes to pay for avoidable waste in processing! The lumber industry, much as it might like to, cannot reject proposition (1) out of hand. If they should even appear to do so, only one interpretation could logically be placed on such a reaction: lumber operators, besides showing a natural reluctance to having their product prices reduced, must feel that waste materials cannot go to market in any great volume except by displacing lumber and other main products on a price basis.

Wherever we turn in the residue utilization picture, we meet the shadow of lumber's decline in all major markets the past quarter-century or more. (To many in the industry, shadow is scarcely the word—substance would be more like it.) A qualified spokesman for the industry was unsparing in his indictment when he analysed the case for this Society three years ago. I refer to the paper presented by Mr. Frank J. Hanrahan, Chief Engineer of the National Lumber Manufacturers' Association. In his report[17], Mr. Hanrahan saw no letup in the pressure to be expected from competitive materials and constructions (which had, as he noted, cut lumber's per capita consumption by more than half from 1909 to 1949—i.e. from 477 bd. ft. to 224 bd. ft.) On the contrary, he saw a continuation of the "technical advancement and development in material and design (of competitive materials) further reducing their cost of manufacture and use." His investigations led him to conclude that "with the exception of railroad ties, lumber is losing ground in practically every specific lumber use. Many lumber markets have disappeared entirely. Others are going rapidly . . . Expanding lumber markets are rare." Why? Not because wood no longer can claim having "more desirable properties for most uses than any other material." But rather, as he put it, that research, cost-reductions in the application of wood, aggressive merchandising, etc. had been sorely neglected.

There are other factors equally well known to you to explain the past inroads made on lumber's markets. And this is not the time or place to go further in an attempt to test Mr. Bentley's prophecy[16] that the softwood sawtimber deficits now showing in official forecasts (Forest Service Reappraisal Reports of 1946) will be overturned by a switch to hardwoods. It is relevant to our purpose to note, though, that competition from wood residue products received scarcely a mention in Mr. Hanrahan's account. Indeed, to make any case here at all, one would have to pick up Louis Stevenson's clue (that the pulp and paper industry lives on wood discarded by the lumber industry[8]) and go on from there to prove that paper and paperboard didn't really open up many new markets for wood—but, for the most part, served lumber's old ones.

Wood Residues in the Balance

We have examined the residue utilization picture from several angles. Our first concern was with the professional groups who have contributed the technical guidance, and how their goals may differ. We then inquired into the basic motives which might induce the general public to support a long-range program for putting more wood waste to use. Finally, we stated the terms in which the economic case for their greater utilization must be made. Of our original questions one remains, and it is crucial: Do the economic forces at work strike a balance favorable to a growing use of these residues?

A number of starting points suggest themselves. The decline in lumber's importance is one that seems singularly appropriate. As a working premise, we need only assume that wood waste would be strongly affected, on its supply side at least, by the outlook for lumber (since a large part of the waste is attributable to the still common practice of logging-for-lumber)—and there may be an interrelationship on the demand side as well.

The prospects for basic materials and resources during the period, 1950–1975, were carefully analysed in the report submitted last year by the President's Materials Policy Commission (the so-called Paley Commission). In this analysis a doubling of the nation's aggregate output of goods and services in real terms, i.e. in dollars of constant purchasing power, was projected. This is equivalent to an average growth rate of 3% per year over the 25 years. Since services requiring no additional material were expected to account for an increasing proportion of the grand total, it was found that the country's requirements for most materials would be met in 1975 with supplies at levels 50–90% above the 1950 level. The needs for paper and paperboard were among those tentatively placed at 50% above the 1950 level. But the Commission could see for lumber only a nominal increase of 10% by the end of this 25 year period, which amounts to a growth rate of about ⅓ of 1% per year. As population, meanwhile, was expected to continue growing through the period at a rate approximating 1% annually, it can be seen that the curve for lumber's per capita consumption is destined, by this report, to fall even further.

Does a levelling off in the demand for lumber mean that wood residues also have a poor prospect for growth in market demand the next 25 years? Not necessarily. Certain economic factors seem likely to be working in their favor and to the possible disadvantage of conventional materials—namely:

(a) Declining supplies of accessible timber of good quality
(b) Strong market demand for materials generally
(c) Rising stumpage prices for round wood
(d) High labor cost inputs in processing standard items (e.g. lumber)
(e) Technological development of new harvesting and processing equipment

Whether residues will be able to capitalize on these advantages remains to be seen. Obviously, residues will only be used in volume when they are cheaper than conventional material (e.g. round wood), pass the minimum standard in quality, and are "obtainable in reasonably sustained and sufficient quantities to justify the capital investment in handling, barking or other necessary equipment for final conversion." The portion in quotes is from R. N. Hammond of Weyerhaeuser in the account he has given of the way prepared chips (from mill residues and salvage logging) met these tests and now supply the new West Coast kraft pulp industry with most of its raw stock. There would have been no such success story to write in the books for residues, however, had hydraulic barkers not been developed which could be used ahead of the mills, thereby increasing the yield of usable, bark-free chips by as much as 73%.[2]

Technology could well decide the issue for residues. If the wave of innovations which began just a few years ago should end shortly, the prospects for residues would be seriously affected. But such an event seems unlikely; indeed, as Prof. Slichter pointed out the other day, "the importance of technological discovery as a determinant of the demand for investment goods is a unique characteristic of the American economy . . . fairly recently acquired . . . and gives us reason to believe 'We can have peace *and* prosperity'."[18] This much is certain: residues still pose a real challenge to technology. Labor costs involved in handling the wood, transportation and concentration costs remain as practical limitations which combine to restrict their use—all much as Dean Garratt noted four years ago.[19] Residues face another handicap, less tangible but nonetheless real, and that is what might be termed "the poor substitute complex." However, by-products in the petroleum and chemical industries have shown time and again that this can be overcome, and wood flour is an example of a forest by-product whose quality, as well as price, has caused it to be preferred over competitive materials.

The sort of collaboration required for success in this search for more ways to use "waste" economically is very well exemplified, it seems to me, in a venture going forward today right here in Maine. I have in mind the Great Northern Paper Company's project for introducing hardwoods into the manufacture of newsprint through the medium of the chemigroundwood process. Here we have a new process developed since the war by university professors in the laboratory (Professors Libby and O'Neill at New York State College of Forestry). The funds were supplied by industry as part of a research program to find a way to counter the rapid depletion of coniferous wood in New York.[20] The new findings were immediately made known through technical bulletins and articles. A company now comes forward, able and willing to stake $30 million for large-scale commercial production on a process that had not gone beyond pilot-plant stage. The hardwoods to be used can only be classed as residues under the extended definition (page 8), since they have until now lacked any commercial appeal. And the final result can scarcely fail to enlist the approval of foresters, chemists, engineers and economist alike: with no increase in the commodity drain on the forest, the sum total of useful goods will be expanded —probably at a saving in power and other real costs.

I can think of no more fitting note on which to close. For this paper, as you can see, has been made up only in part of description and analysis. For the remainder, I had to choose between skepticism and affirmation of faith. The late Justice Holmes, at the age of 83, wrote a Chinese law student a few words of advice that might have been directed equally well to a research worker in the field of wood residues: "HAVE FAITH and pursue the unknown end."

Literature Cited

—— F.P.R.S. Preprint No. 1 (1948), Robert K. Winters, Importance of Economic Considerations in Wood-Waste Utilization Research
1. Journal of Forestry, June, 1952, D. V. Logan, Dissolving Pulp from Southern Hardwoods (Paper presented to SAF Dec. 14, 1951).
2. F.P.R.S. Preprint No. 177 (1951), R. N. Hammond, Utilization of Wood Waste in Manufacturing of Chemical Pulps in the Pacific Northwest.
3. Journal of F.P.R.S., Vol. II, No. 4 (Nov. 1952), Armin Elmendorf, Manufacture of Hardboard out of Wood Waste.
4. Journal of F.P.R.S., Vol. I, No. 1 (Sept. 1951), A. T. Walton, How Insulating Board Products are Made by the Simpson Logging Co.
5. Journal of F.P.R.S., Vol. II, No. 4 (Nov. 1952), Wayne C. Lewis, The Hardboard Industry in the United States.
6. Journal of F.P.R.S., Vol. II, No. 5 (Dec. 1952), Jerome F. Saeman, Status of Chemical Utilization of Wood Waste.
7. Journal of F.P.R.S., Vol. II, No. 5 (Dec. 1952), Lyle F. Watts, Util-

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Wood Chips from Sawmill and Veneer Plant Residues[1]

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Development of paper and paper product business based largely on purchase of raw material from sawmills and veneer plants is described. Author gives details of purchase, handling, transportation and control of quality of chips. Labor costs and investment in equipment and transportation facilities are indicated. It is pointed out that whole log barking will in most cases double the amount of chips available.

THE LONGVIEW FIBRE COMPANY occupies a 160 acre waterfront site on the Columbia River near the city of Longview, Washington. Two of the primary reasons for this particular location were the availability of an ample water supply and the vast quantity of suitable sawmill residues, which, in 1926, was being burned at nearby sawmills.

A container board machine designed for a capacity of 100 tons per day commenced production in 1927. A steady growth during the past 26 years has resulted in the mill now producing daily on 6 machines approximately 700 tons of products consisting of container board, bleached and unbleached kraft paper and converted paper products such as bags, towels, asphalt laminated, creped and treated papers and from the container board, solid and corrugated shipping containers. In addition to the container manufacturing facilities at Longview, the company manufactures containers at plants in Oakland and Los Angeles, California, and also at the wholly owned subsidiary, General Fibre Box Company, Springfield, Massachusetts.

The shipping containers are sold by our own sales organization along the Pacific Coast. Paper and converted paper products are distributed through paper jobbers throughout the area west of the Continental Divide.

The sources of wood to produce these 700 tons per day of product can be divided into the following classifications: sawmill and veneer plant residue, timber salvage, farmer wood lot, logs purchased on the open market and our own timber lands. This discussion will be limited to chips produced from sawmill and veneer plant residues which at the present time account for approximately 75 percent of our wood requirements. Prior to this utilization program such residues were burned. It requires approximately two 200-cubic-foot units of chips to produce enough cellulose fibre to manufacture one ton of pulp.

If all of these chips produced from mill residues were loaded in 20-unit rail cars, they would fill 53 cars per day, 1600 cars per month, or approximately 20,000 carloads per year, which if placed in one train would be 190 miles in length.

At the present time we have 29 contract chip suppliers of which 15 are veneer and/or plywood plants and 14 are sawmills.

There are several considerations involved when a source of chips is potentially available. The anticipated life of the mill must be sufficient to justify the expenditure of funds for a chipper installation and the accompanying conveyors to place chips in the rail car or motor truck.

The cost of transporting from point of origin to Longview is very important since a high freight cost per unit could make the delivered cost in Longview too costly. If the aforementioned factors meet the requirements, it is then necessary to perform an actual wood survey at the mill. In the case of a sawmill, a wood survey team of two men visits the mill and calculates the amount of wood suitable for chips that is presently being sent to the burner or hog. After this survey is completed, the gross revenue from the quantity of chips to be produced is calculated.

It is difficult to generalize as to the total installed cost of a chipper at a sawmill since each installation varies. The cost of equipment with a 250 horsepower synchronous motor, plus a suitable screen, costs approximately twenty five thousand dollars. A considerable expense is often encountered in moving the wood to the chipper, and the chips from the screen to loading facility. These costs vary from a low of a few thousand dollars to as much as thirty thousand dollars. At a typical sawmill producing approximately 30 units of chips per day, two men can generally remove from the waste conveyor enough suitable wood for the 30 units, and one additional man can handle the chip loading and other miscellaneous duties in connection with conveyors, motors and accessorial equipment.

A Summer Veneer Chipper operating with 50 horsepower costs approximately ten thousand dollars, and a screen for this type of chipper will cost from fifteen hundred to forty five hundred dollars. It has been our experience that one man can operate the veneer chipper and something less than a second man can handle chip loading and miscellaneous maintenance on motors and conveyors.

Approximately 85 percent of the chips produced at these twenty-nine mills are transported to Longview via specially equipped and assigned railroad cars. We have developed two particular types of equipment, namely the full drop bottom gondola car with wooden sides extended above the standard gondola so as to obtain an inside height of approximately 10 feet. These gondolas are equipped with a special rake or plow made of a 6-inch angle iron which lies on the floor and is pulled lengthwise to assist in unloading. The other type is a 50-foot automobile car without top. These cars have a slope sheet in each end and nine doors cut in each side. The automobile car is divided into three compartments, each of which has a plow or rake made of a 6-inch angle iron on the floor. Each rake is moved across the car to assist in the removal of chips. At the present time the Longview Fibre Company has in service approximately 365 of these specially equipped cars supplied by five different rail carriers. The rail carriers have assigned these cars to our service, and they will remain in our service as long as we utilize them. The cost of extending the sides of the gondola cars plus the rake or plow averages about $500.00 per car. The removal of the roof from the boxcar, installation of slope sheets in each end, bulkheads, cutting the 9 doors in each side plus the unloading device averages about

(Continued on page 93)

[1] Presented at meeting of the Forest Products Research Society, Pacific Northwest Section, April 28, 1953, at Eugene, Ore.

Modern Trend in Wood Finishing[1]

W. A. McKIM
Reliance Varnish Company, Inc., Chicago 51, Ill.

Development of various kinds of finishing materials are related, along with strong points and weaknesses of each. In addition to current use of lacquers and synthetics grain reproduction as part of the finishing process is described.

THE FINISH FORMULATOR in the early 1920's had a comparatively narrow field of study—comparative, of course, to that of the graduate chemist or formulator of today, who is confronted with a myriad of new raw materials. With specific reference to wood finishes the 1920 formulator's field comprised with minor exceptions water soluble, spirt soluble, and oil soluble body stains, linseed oil based fillers, shellac base wash coats, varnish type pigmented sealers, japan colors as shading or uniforming stains, fossil resin linseed short oil varnishes, and the then new water resistant varnishes made with glycerine esterified rosin and china wood oil.

This relatively simple catalog of raw materials constantly kept the wood finishes manufacturer in a good supply of headaches. Stains, if not of the best water soluble type, were either fugitive (faders) or bleeders, (they penetrated into the top coats). Fillers filled well, but settled hard, skinned and hardened in the container, and the weather (usually damp or rainy periods) was blamed when poor drying puffing, greening, and gray pores resulted. In fact, many of the faults were tolerated because they were not recognized as such. Shellac sealers and wash coats gave very little trouble in application as long as the weather was dry, but certainly did not augment scratch and water resistance of the finish. Pigmented japan colors, used as shading stains were wonderful for high lighting, but were also bad actors in poor drying weather.

As time went on the demand for faster finishing, more durable coatings, and better clarity dictated the trend. The first step in speed up was obtained by curtaining off sections of the finish room and installation of heating coils to dry the varnish. Gradually the heated area was extended to include drying of all items involved in finishing. Finally conveyor systems carrying the goods into the spray booths and thence to the ovens were adopted.

[1] Presented to Ohio Valley Section FPRS. April 24, 1953.

The material improvements can be catalogued as follows:

Stains of the water soluble type (best for permanency and non-bleeding) were converted to N.G.R., or non-grain raising type by solution in selected solvents instead of water. This eliminated the hours of drying time required to dispel the water absorbed by the wood. Next, shellac was replaced by lacquer-type wash coats. These lacquer wash coats, sprayed on over body stain, were compounded in such a manner that:

1. Unruly wood fibres are quickly stiffened and rendered easy to sand off.
2. They also seal off the body stain so as not to disturb it while the filler is being padded and wiped.
3. They make it easier to wipe the filler, all of which results in a cleaner, clearer and better filled finish.

Some finishing shops have carried over the old custom of making their own wash coats, by reducing lacquer sealer with thinner. This practice emanated from expedience and does not produce results equivalent to that derived from properly formulated lacquer wash coats. The fast solvent release, the freedom from zinc stearate, and resins are all factors involved in properly formulated wash coats.

Fillers were gradually developed to eliminate poor drying results, graying in the pore, greening over large areas, swelling or puffing, and its aftermath shrinkage. They have been so formulated that settling is controlled, and wiping made considerably easier. Even with these improvements it was not uncommon to encounter bubbling or pin holing of the top coats, especially on certain types of mahogany and occasionally on walnut and oak. Intensive work on filler formulation eventually eliminated the bubbling bugaboo.

In more recent years speed up and costs savings have been achieved by development of a combination of stain and filler, with the complete elimination of wash coats. There is now on the market combination stain and filler which produces far more uniform results than where the human element controls the amount of body stain, wash coat, and filler applied in individual steps. The advent of new solvents rendering stain solutions compatible with the petroleum solvents commonly used to reduce filler has made this new type of combination stain and filler a commercial success.

I might point out that the stain powders used in these solutions are the same as used in the standard non-grain raising type, and are not of the oil type, (bleeders and fugitive) which are easily miscible with the hydrocarbon solvents used with filler.

After filling it is customary to apply a sealer. Today most sealers contain a stearated pigment to permit easy sanding. This type of pigment will gradually go into solution with elevated temperature, and for this reason, sealers cannot be included in the class known as "hot lacquers."

By 1925 lacquers were on the market as a solution to the slow dry of varnishes. Prior to that certain rubbing varnishes gave beautiful depth or fullness, especially on pianos, but to achieve good results each piece was in the finish room about one month. At that time lacquers for wood were compounded primarily with nitro-cellulose, resins, oil, chemical plasticizers, plus solvents. The resin portion usually consisted of shellac, dewaxed damar, or ester gum. Later, when maleic resins came on the market, and zinc stearate was introduced, lacquers were firmly entrenched in the wood finishing industry. Not only did lacquers rub up clearer than varnish, but it was easier to patch and repair. The one criticism was its low solids and high price. In the early days, the patent situation in regard to the use of low viscosity nitro-cellulose seemed to retard rather than spur the development of durable wood lacquers. The past twenty years have been replete with the introduction of higher solids lacquers, which usually were formulated at the sacrifice of one or more desirable properties.

Good quality clear lacquer systems, including a sealer and two coats of lacquer, will pass the RTMA cold check and print resistance tests while maintaining other necessary properties,

such as adhesion, clarity, non-shrinkage, and mar resistance. We have observed that the sealers and lacquers that meet these requirements usually range between 20 and 23 percent solids. One approach to increasing the solids of the top coat clear lacquers has been "hot lacquers". "Hot Lacquers" are lacquers containing higher solids (approximately 33 percent), which was so compounded that the viscosity can be lowered to spray body by heating to about 160° Fahrenheit. The heating units required to warm these lacquers at first could not deliver sufficient volume per minute at the gun to speed up production. However, there are some units today that can deliver 20 fluid ounces per minute, which is considered sufficient for an average conveyor speed of ten lineal feet per minute.

Where forced drying ovens are available, the natural trend in clear top coats has been to synthetic coatings. Some cynics complain we are back to the old problems of varnish, when synthetics are involved, but this is not so. It is true most synthetics cannot be patched in the same manner as lacquer, but it is possible to sand down repair areas, touch up with color, "burn-in" with shellac sticks and then respray the entire surface. One of the important advantages of synthetics is their excellent build. Not only are they double the solids of cold lacquers, but the fact that synthetics do not redissolve sealers as lacquers do, adds greatly to the apparent hold out.

Top Coats

There are a variety of types of synthetic top coats available. Those in the alkyd and modified alkyd class are difficult to cure in the short baking schedule fixed by conveyor systems. Against their one advantage of higher solid content than lacquer they have the following faults:

1. Are not 100 percent suited to rubbing and polishing.
2. Have a tendency to be self-lifting when re-coated.
3. Are not always pale enough initially or after aging to be used on blond work.
4. Have the bad habit of showing print marks.

In the modified urea formaldehyde class of synthetics, many of the objectionable features of the alkyd synthetics have been overcome. This type of synthetic still has high solids, compared to lacquer, and possesses the following advantages over the alkyd synthetics:

1. Are not self-lifting.
2. Are very pale and stay pale.
3. Cut down relatively easy when sanded and rubbed.
4. Have high print resistance after force drying one hour at 135° Fahrenheit with 35 percent to 40 percent relative humidity.
5. Will go eighteen standard cold check cycles without failure.

Some of the coatings in this class after conversion are unaffected by finger nail lacquer remover, moderate acid or caustic solutions, acetone, alcohol, many medicinal stains and hot dishes. In the past, resistance such as this has been found primarily in phenolic coatings requiring such high curing temperatures that their use on wood was limited. Phenolics also tend to yellow and darken so badly that their use on wood is at a minimum.

There are catalyzed synthetics which will air dry over night sufficiently to rub and polish or pack for shipment. It requires about two weeks aging for these films to gradually convert to the point where most of the physical attributes equal that of the baked film.

Some synthetics are modified with plastics such as styrene, chlorinated rubber, vinyl, and epichlorhydrin base resins. Each fulfills some specific requirement in finishing, and may be the forerunner of an entirely new development during the next decade.

There is a definite trend to pre-finish plywood panels. Beautiful color effects have been achieved in completely finished panels 16x96 in. with clear lacquer top coats sanded and buffed to a rich patina. Other panels are being pre-finished in standard 4′x8′ size with stains, fillers, and synthetic top coats. Although these panels are now being funneled into the wall panel field, it is not too difficult to visualize their being cut down to dimension stock for furniture. The finish is not affected by sawing, or beveling edges, and is highly resistant to scratching. Incidently, tests on susceptibility to burning indicate considerable advantage in the urea type synthetics finish versus nitro-cellulose lacquer finish.

Grain Reproduction

An effort to utilize cheaper grades of wood, unselected for color, has resulted in an increased interest in grain reproduction equipment. Years ago grain printing was accomplished by hand operated cumbersome offset equipment. First a base coat of the desired color was applied, next the ink grain, followed by clear top coats. The very nature of the process made it appeal to the producers of the cheapest grade of furniture. They cut corners, adopted direct printing and went so far as to mechanize the equipment for mass production. Naturally this means a sacrifice in faithfulness of the grain reproduction. As competition increased it was necessary to improve the results. This brought about the mechanization of offset printing equipment. Both the off-set and the direct printing machines were originally suitable only for printing flat pieces before the furniture is assembled.

Machine Types

Today there are two types of machines on the market, namely, the vertical and horizontal, that can print on ready assembled cabinets that are properly designed for this purpose. The objection to the vertical machine is that the pressure is greater at the base than it is at the top and usually has to be augmented by manual treatment which isn't always accurate. Also there is the tendency of the composition rolls to sag, particularly in hot weather. The horizontal machine is much more fool proof, much less expensive to purchase originally, and requires less upkeep. It can be used for assembled square cabinets and has a particular advantage over the vertical machine in that it easily prints the wrap around type, including molded or rounded corners. In addition it will do built-up plywood panels, flat panels, and all types of edge and instrument panels, as encountered on TV cabinets. Needless to say, the resulting work usually is so accurate that the average layman cannot distinguish the printed wood from the real "Mc Coy."

Special Base Coats

Another process to utilize unselect color woods involves applying special base coats which will reproduce the underlying grain when blasted with dry colored pigments suspended in a carrier of fine metal or some other media. This is a patented process, and is expected to go into production in certain plants finishing hollow core doors, plywood panels, and suitably designed furniture.

In summation we can say the trend is towards streamlining finishing steps, to the development of tougher and more resistant top coatings, and to the greater control of the factors influencing the dry and conversion of film forming compositions. The future undoubtedly will reveal finishes endowed with characteristics that are only dreamed of today.

Log Barking For Greater Profit[1]

E. P. IVORY
President, Ivory Pine Company of California

Reviews operation of mechanical barker in use at author's plant, and describes benefits derived from debarking. In addition, potential uses of ground bark are related, with the realization that much research yet needs to be undertaken in this field.

MY OPINION AND BELIEF is that log barking is profitable because it prepares a saw log for quicker and better processing in the sawmill and, secondly, because it produces a by-product that is certainly valuable as a soil conditioner and probably for several other uses.

Two Types of Barking Machines

Two types of equipment for removing the bark from logs have been described. The first, or rossing type, which through the use of a cutter head removes the bark from the log and, at the same time, removes projections such as knots, burls, knobs, etc., produces a relatively smooth cylinder that is ideal for sawing in the mill.

The other type, which tears the bark away from the log through the abrasive action of a high-pressure stream of water, removes all of the bark in small chunks and leaves all of the fiber, including the projecting knots. Such a debarked log is rougher than the original. It is better for paper making because all the wood fiber is preserved, but is obviously not as good from a sawmill standpoint.

The Rossing Debarker

We have had one of these machines in operation for about a year. It functions well in most respects, but does give trouble with the cutter head. In our opinion, the best design of head has not yet been achieved. Also, there is some difficulty in getting parts for the current make, but we presume this will be corrected in time. It does reduce logs to a relatively smooth cylinder and grinds the bark into a fairly fine and usable consistency. On the average, it will debark around 50,000′ of Pine and White Fir logs in eight hours. In our operation, it requires only one extra pond man. Actually, two men must be present during most of the debarking operation but one of them would have to be there anyway to cut the logs in two and feed them into the log well.

The cost of this machine installed was approximately $70,000.00, including a heavy, powerful fan for the disposal of the ground bark. This machine has to be about one-half fan and one-half hog, since many large chunks are sucked into it and need to be beaten up before they are blown through to the collector. It requires a 100 HP motor to operate this fan and approximately 70 HP in addition to run the balance of the barking machinery.

Like all newly designed machines, this has its shortcomings, at least as applied to our job. It will not handle lengths 16-foot or under and, though we are on a long log program, we find that approximately 20% of the logs coming to us are 16-foot or shorter, a condition caused by the tendency of trees to break on the rough ground in which we are operating. We believe this defect can and should be overcome. Then, it is difficult, and in some cases impossible, to handle sinker logs through the machine and this proves quite a factor in an operation where 10% of the logs are of the sinker variety. The correction of the first shortcoming should solve the second. Neither of these factors would prove burdensome in a mill cutting all Douglas Fir or Ponderosa Pine, but where White Fir and Sugar Pine constitute the bulk of the cut it makes quite a difference.

Benefits of Debarking in a Sawmill

What are the benefits to a sawmill of having barked logs. We do not have the figures to prove our statements, but one who has been around a sawmill a great deal cannot but observe that there are some very worthwhile benefits obtained. In the first place, the log can be held more tightly on a carriage because one has solid wood into which the dogs bite every time instead of into bark, which is soft of itself and oftentimes loose. Furthermore, the freedom from projections make it unnecessary for the sawyer to turn the log several times

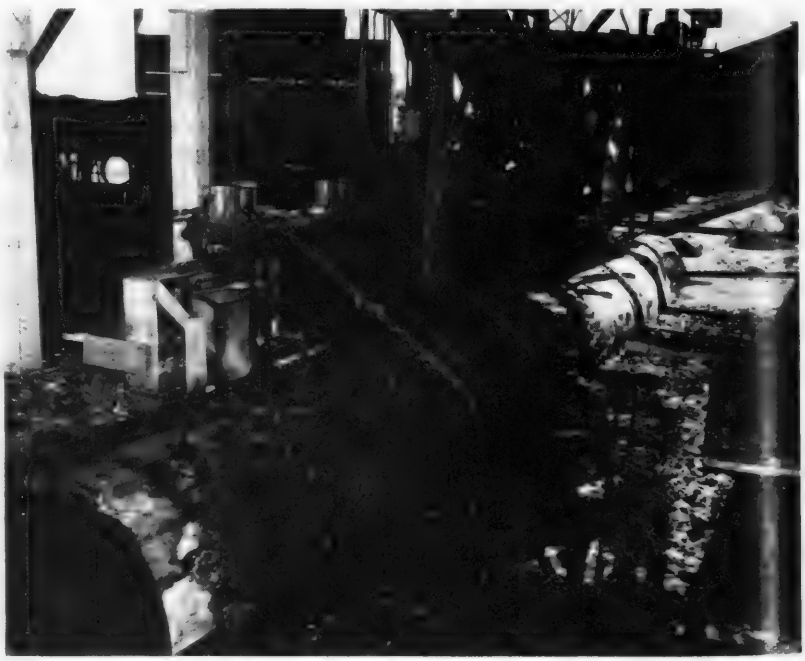


Figure 1.—Debarker described is seen here in action at Ivory Pine Co., Dinuba, Calif. The four chains rotate the log and spiral it forward at the same time. A large and heavily built fan sets up the bark dust and sends it up to a collector from which it can either be sent to the burner or dropped into a truck.

[1] Presented at meeting of the Forest Products Research Society, Northern California Section, May 6, 1953, at San Francisco.

Figure 2.—This group of six debarked logs on the live log deck contains 3100 board feet. Note their general roundness and absence of projecting notes. Such logs can be cut more advantageously and saws last longer.

Figure 3.—Truck and trailer load of ground bark headed for ranch in vicinity of Ivory Pine Co. Acid nature of bark is valuable for alkaline soil in area. Bark breaks down readily when composted to furnish valuable humus element.

to get it in position on the carriage. Because the log is held more rigidly, the lumber produced is more uniform in thickness. Further, there is less "dodging" of the saw. Now, there are many causes of saw dodging, such as dull or poorly fitted saws, but bark and big knots on the surface are frequently causes of this defect and for the barked log these two major causes of poor sawing are removed.

Saws last much longer and retain their sharpness better with barked logs. Any logs that are dragged over the ground pick up sand and gravel and only a portion of this can be removed by immersion in water, spraying, etc. Obviously, if the bark has been removed, this sand and gravel —in our case decomposed granite— is removed with it. If there are spikes or nails in the logs, they are usually detected and avoided if not removed in the debarking process.

Edging of the lumber can be done more accurately when the bark has been removed and the same is true in a smaller degree with the trimming. Your men are handling a less rough, more nearly smooth product all the way through and they respond to it, even to the fact that there is less weight when the flitches thrown off by the head saw need to be rehandled. There is less debris around the mill floor and things are cleaner when logs have been barked.

But it is in the salvage department that barking benefits are most obvious. It is easier for the stock picker because he can see what he has and only has to work with the wood itself. One gets better yield and more accurately prepared salvage material and does it with less work. Then, too, there is the opportunity for chip production of bark free waste, a product that is coming more and more in demand all the time.

Some Potential Uses of Ground Bark

A second source of profit from barking is the use of bark as a by-product. This is something into which we are feeling our way gradually. It lies in two fields—agricultural and chemical. We have had a careful analysis of bark made by Twining Laboratories of Fresno and I wish to give some of their findings. Their first research had to do with the potential use of the ground bark for agricultural purposes. See Table 1.

Note first that the bark is of an acid nature, having a pH running from 3.3 to 4.3. In the area in which our sawmill is located all of the soil is on the alkaline side. Much of the best shows a pH of 7.5 to 8 and some of it goes up to 10 points on the pH scale. It is obvious that the application of this acid bark will bring about some immediate correction and when the pH is low bacterial action and decomposition go on rapidly. The tendency to become humus is greater with bark than with sawdust which, particularly with White Fir and Sugar Pine, is on the alkaline side.

As far as the main soil fertilizer elements are concerned, there is relatively little in the bark. Nitrogen, Phosphate and Potash content is less than one-half of 1% in White Fir bark and far less than one-fourth of 1% in Sugar Pine and Ponderosa Pine. White Fir bark does contain a fair amount of calcium and there is enough of the trace elements in all types of the bark to be worthwhile.

Obviously, with so little fertilizer content, the main function of bark is as an oil conditioner. It does break down very readily. We find that if bark dust is merely piled up and given a small amount of water, it will develop heat and break down in the course of three or four months. If one adds a small amount of nitrogen, either in chemical form or in the form of manure, and then introduces a ni-

(Continued on page 94)

Table 1.—AN ANALYSIS OF GROUND BARK TO DETERMINE THE PRESENCE OF ELEMENTS VALUABLE FOR USE AS A FERTILIZER OR SOIL CONDITIONER

Element	White Fir pH = 4.3	Sugar Pine pH = 3.3	Ponderosa Pine pH = 4.0
Nitrogen (N)	0.22%	0.14	0.13
Phosphoric Acid (P_2O_5)	0.20	0.03	0.02
Potash (K_2O)	0.10	0.04	0.04
Lime (CaO)	1.33	0.19	0.29
Trace Elements	0.05	0.13	0.29
Total Inorganic Matter	2.90	0.53	0.77
Total Organic Matter	97.10	99.47	99.23

Table 2.—WATER EXTRACTIVES OF BARK, BY WEIGHT OF WATER FREE BARK

	White Fir	Sugar Pine	Ponderosa Pine
Insolubles	1.67%	6.82%	0.67%
Non-tannins	11.66%	11.68%	9.08%
Tannin	5.37%	5.88%	1.58%
Non-extractives	81.30%	75.62%	88.67%
Total	100.00%	100.00%	100.00%
Total Extractives	18.70%	24.38%	11.33%
Soluble Extractives	17.03%	17.56%	10.66%

Hydraulic Log Barking[1]

E. I. FLATEBOE

President and General Manager, Sumner Iron Works, Everett, Washington

Reviews various major designs of hydraulic-type barkers, describing main operating features of each type. In addition, author reviews the advantages of hydraulic log barking. Tables included give basic estimated costs and returns from hydraulic log barking.

I BELIEVE THAT EVERYONE present here has seen or at least knows about whole log hydraulic barkers or hydraulic slab barkers and their importance in the saw mills and pulp mills of today. The idea of this paper is to help clear up some of the points not generally known and to bring together some of the facts which appear widely scattered throughout the available literature.

To begin with, hydraulic barking has been studied by mill operators for quite a few years. It is believed that the Crown Zellerbach Corporation started it; just how many years ago I do not know. I do believe, however, that it was given up by reason of high first cost and operating cost, although the machine never got into production.

During 1940, or thereabouts, the Weyerhaeuser Timber Company at Longview, Washington designed a hydraulic round log barker, known now as the Weyerhaeuser type Barker. At approximately the same time, the Crown Zellerbach Corporation at Port Townsend also designed a whole log barker which has now become known as the Crown Zellerbach type, patented by Mr. Harry E. Bukowsky. Considerable experimental work was done by both firms before the final decision was made to go ahead with a full size production machine. Sumner Iron Works, in both cases, had the privilege of building the major components of these machines.

The Weyerhaeuser type, like the Crown Zellerbach type Barker, rotates the log. In the first case the log is continuously rotated while the water stream is applied longitudinally to the bark at high speed. In the case of the Crown Zellerbach type Barker the log is revolved between centers much the same as a peeler log in a veneer lathe. The high pressure water stream is applied with a slow longitudinal nozzle movement, thus removing the bark spirally from the log.

I believe that there are three of the Weyerhaeuser type Barkers in operation; one in Everett, one in Longview, and one at Powell River, B.C. Four of the Crown Zellerbach type machines were built and I believe are still in use. These are at Port Townsend, Port Angeles, and Hoquiam, Washington and at Oregon City, Oregon.

Since the two types of machines mentioned above were built, another version of the hydraulic barker has been developed by the Worthington Pump and Machinery Company. One of these is now in operation at the Soundview Division of the Scott Paper Company in Everett, and one at the St. Regis Kraft Company in Tacoma, Washington. These barkers embody a different principle. The log is not rotated, but travels straight through the barker with three batteries of nozzles applying the stream and set at 120°. For a large diameter log this may require more than one pass through the barker.

Closely following the development of the Worthington, is the so-called Bellingham type, again embodying the principle of rolling the log and moving the stream slowly longitudinally across the length of the log, thus spirally removing the bark. This later development differs from the Crown Zellerbach and Weyerhaeuser types in that the log is positively rotated by means of special trunnion wheels having a sufficiently corrugated surface to rotate the log with or without any bark and at a fairly high r.p.m. A total of 19 of these barkers have been installed or are now being built as shown on the list attached to this paper.

They are now built in sizes to handle from 8′ to 44′ long logs ranging from 6″ to about 10′ in diameter. Since the original Bellingham type Barker was designed and patented by Mr. E. Eckholm and Mr. V. C. Haner of Puget Sound Pulp & Timber Company at Bellingham, Washington, a number of changes from the original machines have been made, with a reduction in maintenance costs and, perhaps, a higher efficiency. For example, in order to provide certain flexibility, a number of high pressure rubber hoses were used in the original models. This proved to be a point of rather high maintenance cost and, as a result, they have been completely replaced by high pressure steel swing joints.

The Sumner Iron Works, with their affiliates, the Canadian Sumner Iron Works, Ltd., at Vancouver, B. C., have built all of these latter machines under exclusive manufacturing rights granted by the Puget Sound Pulp & Timber Company. This type of barker is, in the writer's opinion, the most flexible of any hydraulic round log barker on the market today.

Both the log rolling device and the nozzle carriage are usually driven by means of a direct current motor so that the turning wheel r.p.m. and the longitudinal speed of the nozzle carriage can be varied at will to suit the logs. In the latter machines the nozzle may be rotated 360° and is easily controlled for strip barking or cleaning around a burrow or big knots. Poor logs, even with short limbs, may be barked as the branches will go between the turning wheels. Rotted portions of a log may be easily removed with the high pressure jet of water. Bad ends on the log offer no difficulties.

Figure 1.—Original Bellingham-type barker installed at Puget Sound Pulp and Timber Co.

[1] Presented at meeting of the Forest Products Research Society, Northern California Section, May 6, 1953, at San Francisco.

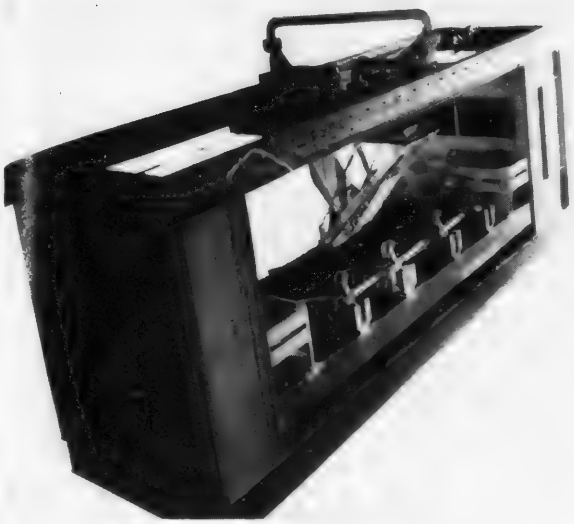


Figure 2.—Unit-type barker designed for barking logs up to 60 in. in diameter and 24 ft. long.

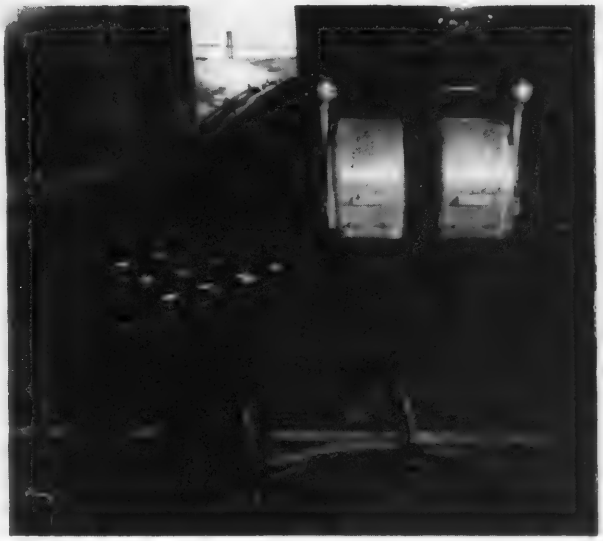


Figure 3.—Operator's controls on large sawmill log barker at Weyerhaeuser Timber Co.'s "B" mill at Everett, Wash. Machine barks logs up to 110 in. in diameter and 44 ft. long.

If you have the time, the moving picture taken at Bellingham will show the original of this type barker at Puget Sound Pulp & Timber Company. The other film shows one of the newer machines at the Mill "B" operations of the Weyerhaeuser Timber Company in Everett, Washington.

Another type of hydraulic log barker has been developed by Mr. Frank Swift of the Crown Zellerbach Corporation and is now handled by the Hansel Engineering Company. This type, in one respect, is similar to the Worthington in as much as the log goes through without turning. The spray is applied through a revolving spray mechanism, taking off the bark spirally. Quite a few of these barkers have been built but to my knowledge, for medium size logs only, or, for up to about five foot diameter logs.

Several Simons barkers are also now in use. Designed by Howard A. Simons of Vancouver, B.C., the log in this case also goes through the unit without being revolved. The water stream is applied to the log through a rotating nozzle with a vertical spindle, one nozzle above and one under the log. From what the writer has seen, this machine is apparently doing a very good job. Like the Hansel, it has so far been built for medium size logs only.

The Allis–Chalmers Stream Barker, which was developed by the Allis–Chalmers Manufacturing Company in Milwaukee, Wisconsin, is primarily designed for small diameter, eight foot pulp wood. A large number of these units are in use in the various pulp and paper mills throughout the country. The machine is usually installed with two pumps, one of which is a booster pump so that a variety of pressures are available for use with the various species of wood to be barked. This barker is a packaged type unit but, so far as I know, has only been made for short logs 8′ or 10′ in length and approximately 24″ maximum diameter.

Advantages of Hydraulic Log Barking

A. Chip Yield: The best figures which we have available indicate that in a mill where no barking is done, that is where bark-free wood is picked from the refuse conveyor, the chip yield will average slightly over 0.2 units per thousand board feet of lumber cut. On the installation of hydraulic log barking facilities, this yield increases to slightly under 0.6 units of chips per thousand board feet. This figure will vary tremendously depending on size and type of logs being cut.

B. Additional Recovery of Lumber: One Canadian operator reports an average gain of $3.50/MBF of logs over-run when a hydraulic barker was installed. The average of figures available to us approximates 5%.

C. Saw Maintenance and Increased Saw Life: This point has grown to be a major advantage in hydraulic barking. One large operator actually reported to us that their saw costs were cut in half after installation of the barking facilities.

Saw changes are reduced about in the ratio of 3:2. Saw breakage is reduced because of elimination of rock and other abrasive material embedded in bark.

D. Upgrading of Lumber: The actual increase in value from upgrading of lumber is very difficult to determine but this is one of the greater benefits of hydraulic barking. One source states that about 5% is upgraded from $70.00 to $90.00 per MBF.

E. Cleaner Mill: Mills having hydraulic barker installations report elimination of most of the clean-up crew on the sawmill deck. A safer mill also results from having a cleaner deck in the sawmill.

F. Increased Production: Most operators report a greater production of up to 10% per man day due to less down time for saw changes and other production factors.

I have attempted in Table I to give an estimated cost of hydraulic log barking. You will note that water costs are not included in these figures since this will vary over such a wide range in the various mills.

Table II shows the estimated daily returns after installation of a Hydraulic Log Barker. The latter figure does not include savings in cleanup labor or greater saw life due to the difficulty of determining these figures. The basis in both calculations is a sawmill cutting 200,000 feet per day.

Water Consumption

The size of water pump required with these machines depends upon a large number of factors: average diameter of log, capacity requirements, and species all enter into the figures. At least one mill that we know is using salt water. Most installations have a water supply to the machine of from 600 to 1200 gallons per minute at 1300 p.s.i. Pump motor power requirements average 1 HP per gallon of water.

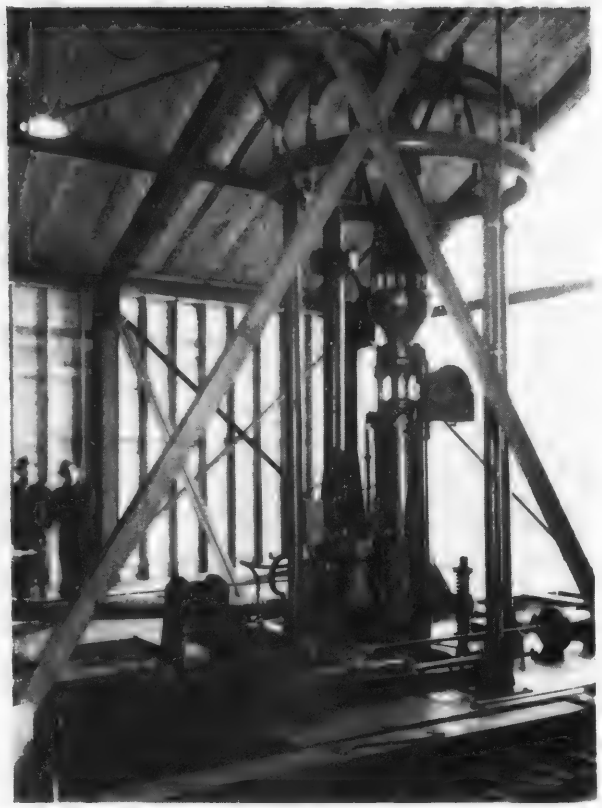


Figure 4.—Nozzle carriage, water supply piping and manifold for barker shown in figure 3.

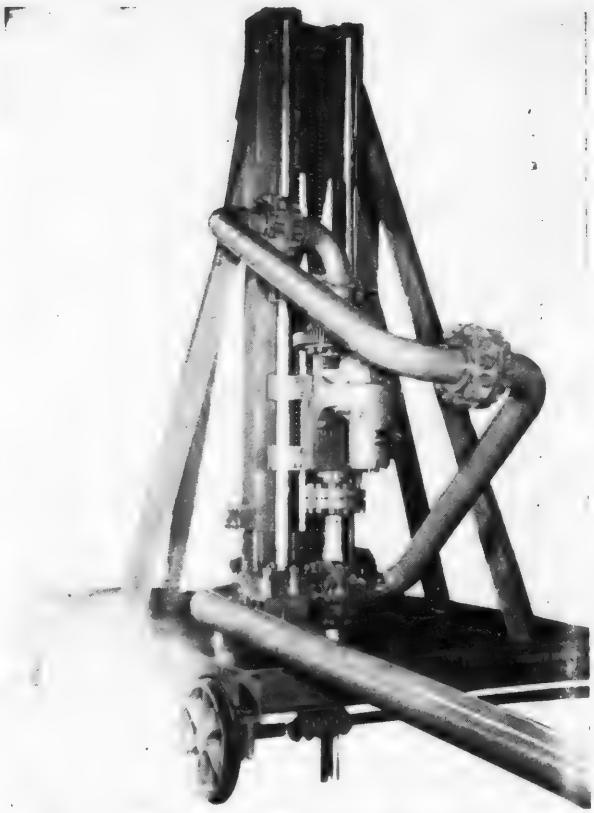


Figure 5.—Water supply piping and nozzle carriage for large sawmill barker installed at White River Lumber Co., Enumclaw, Wash. Note that all rubber hoses shown in figure 4 have been eliminated and replaced with steel swing joints as shown, to lower maintenance costs.

With installation of suitable screening apparatus, barking water can be reused; a factor which is of much importance in localities of low water availability.

Comparison of Hydraulic with Mechanical Barkers

Information received from manufacturers of mechanical barking equipment indicates that the cost of barking will approximate $1.00 per 1000 BF although at a considerable loss in chippable wood.

In closing this section on hydraulic log barking, I would like to add that the case for a sawmill hydraulic barker nearly always will hinge around the available chip market.

Hydraulic Slab Wood Barkers

Also, just a few words about hydraulic slab barkers. Those developed to date are practically all of the same general design. The slab enters the barking chamber, passes under the nozzle, and leaves the machine either by means of chains or rolls.

The slab barker nozzles have been made in various sizes and shapes. Some apply the stream through a straight manifold at right angles or at an oblique angle to the axis of the slab. Some units utilize an oscillating nozzle. It has been found that the oscillating type nozzle does the best job for heavy bark such as heavy fir slabs.

One of the major advantages of the oscillating type nozzle is low overall water consumption with wide slabs. For example, with a 6" nozzle width and a water supply of 600 gpm, we have a water concentration of 100 gpm/inch of nozzle width. With the oscillating mechanism, this high water concentration is utilized over the total slab width of say 28". If a stationary nozzle was employed, a water supply of 2800 gpm would be required for the same water concentration.

These slab barkers, depending upon size, amount of water used, pressure and horsepower, and wood species, will bark from five to 12 cords of wood per hour.

Table 1.—ESTIMATED COST OF HYDRAULIC LOG BARKING[1, 2]

Depreciation: $350,000—10 Years—240 Days/Year	$145.83
Power: 6500 KWM @ 0.007	51.24
Labor: 24 Man hours @ $2.00/Hour (Including Chippers)	48.00
Maintenance	40.00
Total Daily Cost	$285.07

$$\text{Cost/MBF} = \frac{285.07}{200} = \$1.42/\text{MBF}$$

[1] Mill Basis 200 MBF/D.
[2] Water Cost not included.

Table 2.—ESTIMATED DAILY RETURNS WITH HYDRAULIC LOG BARKING[1,2]

5% Increased Yield at $70.00/M	$700.00
Upgrading 5% at 70.00–90.00 Daily	200.00
Increased production 7% at 50.00–70.00	280.00
Increased Chip Yield 0.3 units to 0.6 units	360.00
Total daily returns	$1,540.00

$$\text{Return/MBF} = \frac{1540.00}{200} = \$7.70$$

[1] Increased Saw Life and Cleanup Savings not included in above.
[2] Mill basis 200 MBF/Day.

INSTALLATION LIST—SUMNER BELLINGHAM TYPE HYDRAULIC LOG BARKERS

The Barkers listed below are all of the same size as originally installed in the Bellingham plant of Puget Sound Pulp & Timber Company.

1. Puget Sound Pulp & Timber Co., Bellingham, Washington
2. Fibreboard Products, Inc., Antioch, California
3. Crown Zellerbach Corporation, Port Townsend, Washington
4. Crown Zellerbach Corporation, Camas, Washington
5. Rayonier, Incorporated, Shelton, Washington
6. Alaska Pine & Cellulose, Ltd., Woodfibre, B.C., Canada
7. Alaska Pine & Cellulose, Ltd., Port Alice, B.C., Canada
8. Columbia Cellulose, Ltd., Prince Rupert, B.C., Canada
9. Paper Makers, Pty. Ltd., Burnie, Tasmania (Australia)
*10. Ketchikan Pulp Company, Ketchikan, Alaska

(Continued on page 94)

Effect of Heat Upon the Dimensional Stabilization of Wood[1]

R. M. SEBORG, HAROLD TARKOW, and ALFRED J. STAMM
Chemists, Forest Products Laboratory,[2] Forest Service, U. S. Department of Agriculture

Describes investigation that disprove the hypothesis that stabilization by heat is a cross-linking reaction. Analyses of tests employed indicate that unless some way can be found to separate the dimension-stabilizing from the embrittling reactions, which does not seem probable at present, the commercial use of wood stabilized in this way will be quite limited.

Introduction

HEATING WOOD TO TEMPERATURES considerably above normal seasoning temperatures is the oldest, simplest, and cheapest means now known for stabilizing the dimensions of wood, but the treatment, unfortunately, embrittles the wood significantly *(8, 9, 13)*.[3]

Dimensional stabilization of wood with heat has been previously shown to be dependent upon a combination of temperature and time. The time required to attain a given antishrink efficiency (dimension change of the control minus the dimension change of a matched heated specimen divided by the dimension change of the control between the oven-dry and the water-soaked conditions, or between two different relative humidities, expressed in percent) increases in a logarithmic fashion with a decrease in temperature *(8)*. An appreciable weight loss accompanies dimensional stabilization. The loss is greater per unit time when the wood has free access to air than when heated beneath the surface of a molten metal *(6, 8)*.

Dimensional stabilization by heat is accompanied by a loss of water of constitution of the wood. This fact, coupled with limited data showing that dry heat is more effective than moist heat, was the basis for the hypothesis that stabilization by heat, like the reaction of wood with formaldehyde *(12)*, is a cross-linking reaction *(9)*. The postulated cross linking was pictured as an oxygen linkage (that is, an ether) formed by water splitting off between two hydroxyl groups on adjacent swelling units.

It was felt desirable to check this hypothesis and to find, if possible, means of avoiding the undesirable embrittlement that has thus far prevented the commercial use of this otherwise promising means of stabilizing the dimensions of wood. On the basis of support from the Office of Naval Research, an investigation was initiated at the Forest Products Laboratory to obtain more information on this heat reaction and its control.

Nature of the Thermal Reaction

A series of tests was made to determine if the thermal reaction is really one involving the formation of ether cross links.

Tests were made on the swelling of heated and unheated wood in several different agents that cause normal wood to swell more than it does in water. If ether cross links were formed on heating, the swelling in concentrated sodium hydroxide, morpholine, and pyridine should be significantly less than the swelling of the unheated controls, as none of these liquids is capable of breaking ether linkages. The data given in table 1 for the swelling of unheated and heated spruce and maple cross sections show that with maple, heat treatment reduces the subsequent swelling only in water. In fact, the heated sections of maple swelled more than the controls in all liquids but water. With softwoods (spruce) heat treatment reduced the swelling in water, had a slight effect in reducing the swelling in pyridine, and increased the swelling in sodium hydroxide more than 35 percent. Previous work *(12)* showed that formaldehyde-stabilized wood undergoes less swelling in all of these liquids than does untreated wood. This indicates that the dimensional stability resulting from heat treatment is probably not due to the formation of ether cross links between swelling units, as in formaldehyde treatment.

In order for cross linking to occur between the various swelling units, it would seem that the separation of these units should be within rather definite limits, presumably not more than one molecular diameter of water apart. Cross linking should thus occur readily in dry wood or in wood at low moisture content, but not in completely swollen wood. Experiments were hence conducted on heating both dry and bulked-out (that is, swollen) matched specimens and determining their subsequent antishrink efficiencies.

Preliminary bulking experiments in which diphenyl oxide replaced the acetone in acetone-swollen cross sections of Sitka spruce and glycerine replaced the water in water-swollen sections were inconclusive, as the diphenyl oxide caused more shrinkage than was desired under the heat treatment and the glycerine tended to pulp the wood. The partially bulked specimens heated in diphenyl oxide, however, gave the same subsequent antishrink efficiency as the unswollen sections heated in the same medium. The experiment did show conclusively that oxidation by atmospheric oxygen is not the cause of stabilization, for heating of the swollen specimens was carried out in the absence of both atmospheric and internally occluded oxygen.

The bulking of the wood cross sections was most effectively accomplished by causing potassium iodide to diffuse from a concentrated aqueous solution into the water-swollen cell-wall structure, followed by oven drying to remove the water. The oven-dry specimens retained 65 percent of their water-swollen volume even after drastic heating. This corresponds to an average separation of the swelling units of about three molecular diameters of water, instead of the five for completely swollen wood *(7)*. These specimens, together with unswollen controls, were heated in a bomb at 210° C. for 5 hours. The potassium iodide was leached from the swollen specimens. The antishrink efficiency of

[1] Report of work done under Order No. NAonr 42–47 for the Office of Naval Research. Presented at the Cellulose Division meeting of the Amer. Chem. Soc. in Milwaukee, April 1, 1948.

[3] Italic figures in parentheses refer to Literature Cited at the end of this report.

Underlined figures in parentheses refer to Literature Cited at the end of this report.

Table 1.--Swelling of heat-stabilized sugar maple and Sitka spruce cross sections in various liquids compared with the untreated controls

Species	Treatment	Tangential swelling in:			
		Water	18 percent sodium hydroxide	Morpholine	Pyridine
		Percent	Percent	Percent	Percent
Sugar maple...	Unheated control..	9.7	14.1	13.2	12.6
Do.....	Heated 5 hours at 210° C. in air...	5.3	15.6	15.9	13.7
Sitka spruce..	Unheated control..	10.0	13.2	.....	12.5
Do.....	Heated 7 hours at 230° C. in air...	6.6	18.2	.....	11.7

Table 2.--Properties of paper heated under various conditions

Property	Condition during heating	Extent of heat treatment					
		180° C. 2 hr.	200° C. 2 hr.	200° C. 5 hr.	220° C. 2 hr.	220° C. 5 hr.	240° C. 2 hr.
Color	S[1]	White	White	White	White	White	White
	D[2]	Tan	Light brown	Brown	Dark brown	Brown black	Brown black
		Percent	Percent	Percent	Percent	Percent	Percent
Relative gain in weight at 90 percent relative humidity	S	93	90	88	86	85	81
	D	93	91	86	88	85	85
Relative fold resistance	S	66	85	43	22	2	3
	D	0	0	0	0	0	0
Relative tensile strength	S	87	92	84	78	70	68
	D	74	51	35	28	19	25

[1] Paper swollen in glycerine. Heated while submerged in glycerine.
[2] Paper not swollen. Heated dry.

both the originally swollen and the unswollen heated specimens was then determined, the former giving a value of 33 percent and the latter 31 percent.

If this dimensional stabilization were due to the formation of ether cross linkages, it should have been considerably greater for the heated unswollen wood than for the heated swollen wood because of the much more favorable molecular spacing of the structural units in the unswollen wood. The fact that the antishrink values were practically identical indicates that the dimensional stabilization must be due to some other cause.

As an aid in understanding the transformation occurring when wood is heated, it was of interest to isolate those transformations due only to the stable polysaccharide components of wood. For this purpose, the heat treatment of pure carbohydrate material was next considered.

A bleached sulphite paper was cut into 5- by 6-inch sheets. After matched grouping, some of the sheets were swollen in water and the water was replaced with anhydrous glycerine. The swollen and nonswollen sheets were then heated under various temperature-time conditions. After the treatments, they were thoroughly washed, conditioned, and tested for hygroscopicity, fold resistance, and tensile strength. The data are presented in table 2. The following conclusions may be drawn from the table:

1. Heating paper in the dry condition brings about appreciable darkening. If the paper is swollen in glycerine and heated while submerged, no darkening occurs. With wood, however, equal darkening is obtained under both conditions. This suggests that the hemicelluloses or lignin in wood are undergoing thermal transformations that do not require oxygen.

2. The relative hygroscopicity (relative weight increase between 0 percent relative humidity and 90 percent relative humidity) is approximately the same regardless of whether the paper is heated while swollen or not. This

fact agrees with the observations made when swollen and nonswollen wood are heated, and adds further weight to the belief that cross linkages do not form on thermal treatment. Again, the data show that oxidation is not responsible for the reduction in hygroscopicity, for those specimens heated while swollen and submerged were not only out of contact with atmospheric oxygen, but in the process of swelling the specimens, occluded oxygen must have been driven off.

5. The specimens heated while swollen showed a gradual reduction in fold resistance. The specimens heated dry showed an extremely rapid drop in fold resistance to practically zero.

6. The specimens heated while swollen showed a very gradual drop in tensile strength. The specimens heated dry showed a rapid drop in tensile strength.

Cotton fabric that was heated for 6 hours at 200°, 220°, and 240° C. in the dry and in the glycerine-swollen states, like the paper, did not darken when heated in glycerine, but progressively darkened when heated in air. Appreciable reductions in hygroscopicity occurred in both cases. The fabric swollen in glycerine should not have given the oserved reduction in hygroscopcity if the reaction were one involving the formation of cross links.

Effect of Heating Under Different Conditions Upon the Properties of Wood

In order better to understand the effect of heat upon the dimensional stabilization and physical properties of wood, a number of experiments were performed in which wood was heated in different gaseous media under atmospheric pressure or under confined conditions that allowed the pressure to build up, and under different conditions of moisture-content, temperature, and time.

Adjacently cut cross sections of ponderosa pine sapwood were used for the experiments. The sections heated under atmospheric pressure were 1¾ inches in the radial direction, 1¼ inches in the tangential direction, and ⅛ inch in the fiber direction, except the specimens for toughness tests, which were $\frac{3}{16}$ by ⅜ by 3 inches in the fiber direction. The sections that were heated in pressure bombs were $\frac{3}{16}$ inch thick in the fiber direction by 3 inches in either the radial or the tangential direction and ⅜ inch in the other transverse direction.

Specimens heated in air were suspended in glass jars from metal hooks fastened to loosely fitting asbestos-board tops. In order to avoid spontaneous combustion at the higher temperatures, the air was not circulated. Distillation vapors were, however, able to escape without appreciable amounts of air entering, hence, no pressure developed in the jars. The jars were suspended in an oil bath, thermostatically controlled to within 1° C. of the desired temperature.

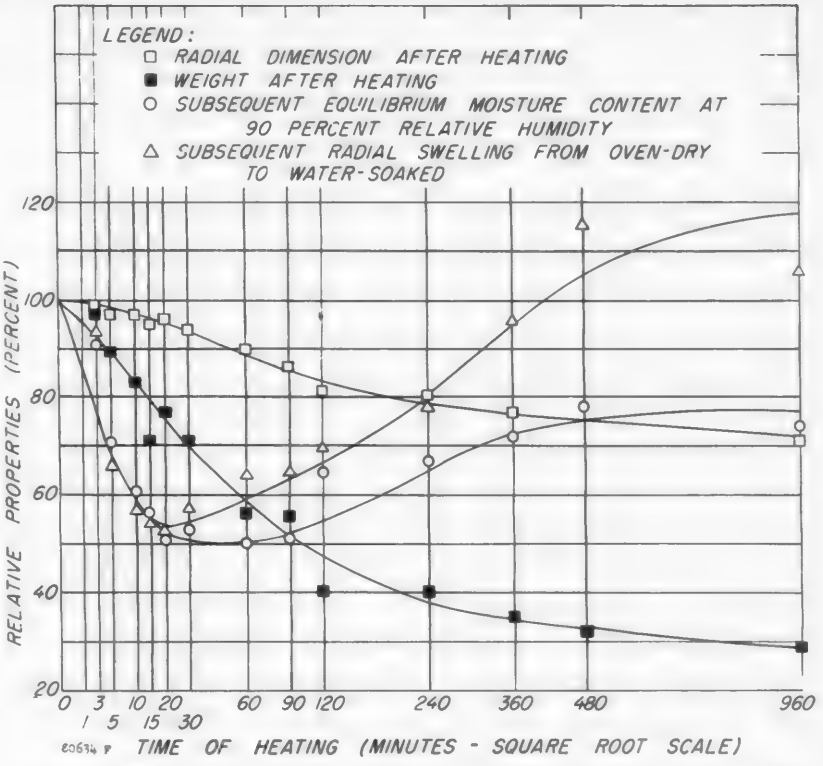

LEGEND:
□ RADIAL DIMENSION AFTER HEATING
■ WEIGHT AFTER HEATING
○ SUBSEQUENT EQUILIBRIUM MOISTURE CONTENT AT 90 PERCENT RELATIVE HUMIDITY
△ SUBSEQUENT RADIAL SWELLING FROM OVEN-DRY TO WATER-SOAKED
RELATIVE PROPERTIES (PERCENT)
120
100
80
60
40
20
0 1 3 5 10 15 20 30 60 90 120 240 360 480 960
TIME OF HEATING (MINUTES - SQUARE ROOT SCALE)

Figure 1.—Effect on properties of ponderosa pine sapwood cross sections when heated at 300° C. in air at atmospheric pressure for different periods of time.

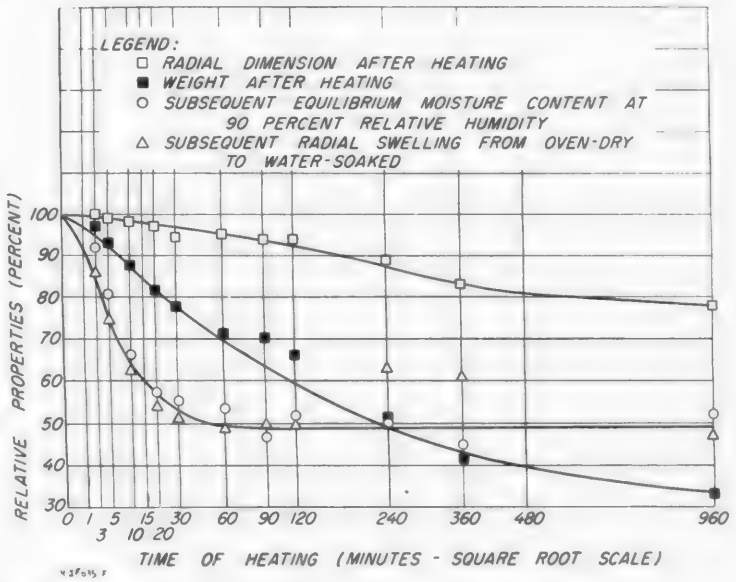


Figure 2.—Effect on properties of ponderosa pine sapwood cross sections when heated at 300° C. in nitrogen at atmospheric pressure for different periods of time.

The specimens heated in nitrogen were similarly handled except that the air was removed by a high-vacuum pump and nitrogen was admitted into the jars. During the heat treatment, a slow stream of preheated nitrogen was passed through the jars to avoid the reentrance of air.

Specimens heated in an enclosed system were placed in small brass bombs ½ inch in internal diameter and 3½ inches long. The bombs were heated by immersing them in the oil bath for various periods of time and

were then cooled by quickly immersing them in cold water.

Specimens were heated in the bombs under three different moisture-content conditions; oven-dry, in equilibrium with 97 percent relative humidity (about 25 percent moisture content), and in equilibrium with 97 percent relative humidity with additional water added to the bomb in an amount equal to 165 percent of the weight of the wood.

The specimens heated in the bombs were treated with hot water to extract soluble products that might have been formed, and were then air-dried. All specimens were oven-dried, and the loss in weight and the decrease in the long dimension were determined. The specimens wre then subjected successively to 30, 65, and 90 percent relative humidity, and finally to liquid-water immersion followed by conditioning at 90, 65, and 30 percent relative humidity. They were weighed and measured after coming to equilibrium at each relative humidity and were measured after water soaking. Moisture content and dimension changes relative to those for the unheated controls were calculated for each of the exposure conditions. As the relative moisture content at 90 percent relative humidity under adsorbing conditions, and the relative dimension change from the oven-dry to the water-soaked condition, best illustrate the reduction in hygroscopicity and the anti-shrink efficiency that occurs, only this part of the equilibrium data is presented in figures 1 to 5. Figure 6 gives the relation of antishrink efficiency resulting from heating the dry specimens of figures 1 to 5 to the weight loss. Figures 7 and 8 show how the relative equilibrium values change with changes in exposure conditions.

Figure 1 gives the relative property changes that occur on heating oven-dry sections in air at 300° C. for different periods of time. Time is plotted on a square-root scale so as to compress the plot and to make possible the plotting of zero time. The slight inflection in the curves for the shortest heating times is, undoubtedly, due to the fact that a good proportion of this time was required for the specimen to come to the temperature of the oil bath.

All previous heating experiments at this high temperature have been for shorter periods of time *(8)*. The fact that a minimum relative hygroscopicity and relative swelling are finally reached has not been previously observed. It is of interest that the relative hygroscopicity and swelling are equivalent up to about the minimum value, but beyond this, they diverge. It is possible under these conditions

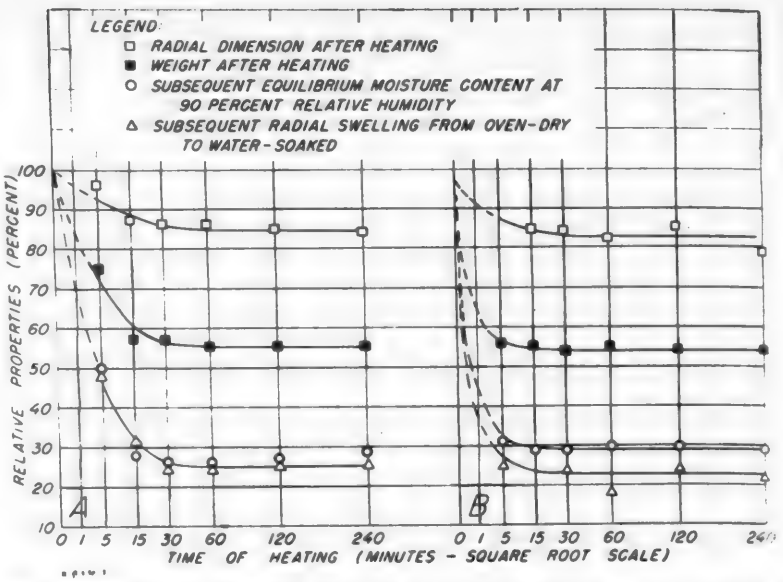


Figure 3.—Effect on properties of ponderosa pine sapwood cross sections when heated at 300° C. in closed containers for different periods of time. A, wood originally oven-dry; B, at 25 percent moisture content.

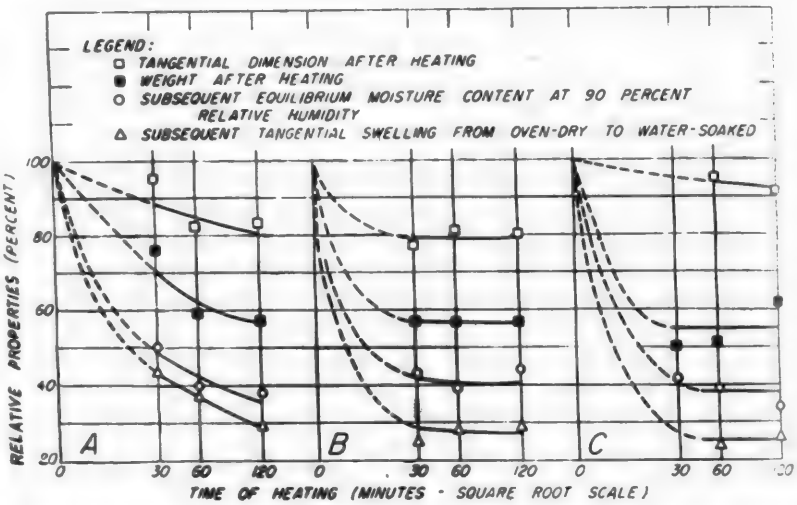


Figure 4.—Effect on properties of ponderosa pine sapwood cross sections when heated at 260° C. in closed containers for different periods of time. A, wood originally oven-dry; B, at 25 percent moisture content; C, at 165 percent moisture content.

actually to obtain a negative dimensional stabilization, that is, a stabilization whereby the heated specimen swells more percentagewise than does the control.

Figure 2 gives the corresponding data for heating oven-dry specimens at the same temperature in nitrogen. The relative weights are but slightly higher than when the specimens were heated in air. Had an appreciable amount of air been available in the experiments shown in figure 1, considerably greater weight losses would have occurred. It is of interest that the relative radial dimensions, although slightly higher than for the specimens heated in air, are practically the same when the comparisons are made at the same relative weight.

The relative hygroscopicity and relative swelling reach about the same minimum value as when the specimens are heated in air, but they remain at this value even though there is still a continued loss in weight with increasing time. In this case, relative hygroscopicity and relative swelling are practically equivalent over the entire range.

Figure 3 gives the data for heating of the oven-dry and humidified specimens in the small sealed bombs at 300° C. It is of interest that under these conditions minimum relative weight, radial dimension, hygroscopicity, and swelling values are rapidly attained and that they remain constant with continued heating. The values attained for dry and for moist wood are

practically the same. The more rapid attainment of the minimum values when moisture is present, is presumably due to the better thermal conductivity of moist wood.

Figure 4 gives similar data to figure 3, except that the heating temperature was lower, namely, 260° C. The results were similar except that a longer time was required to attain the minimum relative property values. When large amounts of water were present (fig. 4, C), the tangential dimension was, for some unexplainable reason, abnormally high.

Figure 5 gives the data for heating in the bombs at 205° C. In this case, the final relative weights and tangential dimensions are quite similar for the specimens heated dry, for the specimens heated at a moisture content of 25 percent, and for the specimens heated in the presence of a large excess of water. It is of interest that the relative hygroscopicity and swelling increase quite appreciably with an increase in moisture content. Stamm and Hansen *(9)* found that at a still lower temperature (165° C.) a negligible antishrink efficiency was obtained when water was added to the bomb, whereas significant antishrink efficiencies were obtained when the wood was heated in the dry condition. It was partially on the basis of this finding that they postulated the formation of ether cross links. The fact that the presence of an excess of moisture does not reduce the resulting antishrink efficiency at 260° to 300° C., as is shown in figures 3 and 4, is, however, not compatible with the old hypothesis.

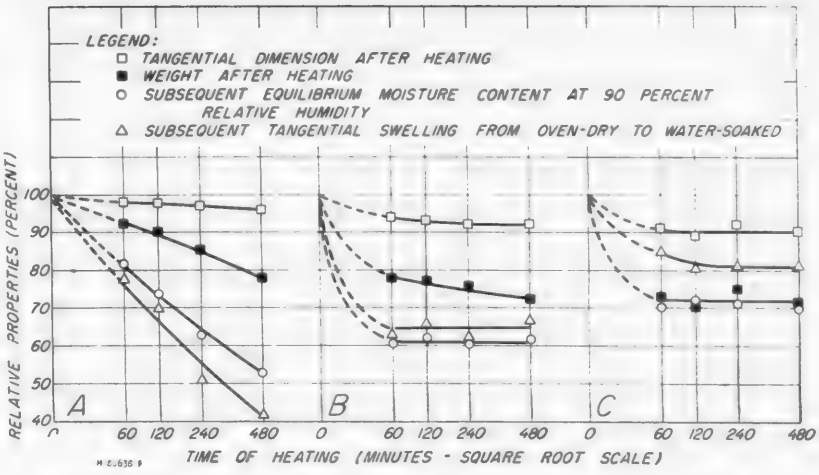


Figure 5.—Effect on properties of ponderosa pine sapwood cross sections when heated at 205° C. in closed containers for different periods of time. A, wood originally oven-dry; B, at 25 percent moisture content; C, at 165 percent moisture content.

Figure 6 gives the compiled data taken from figures 1 through 5 for the antishrink efficiency measured between the oven-dry and the water-soaked condition plotted against the loss in weight. The antishrink efficiency for losses in weight up to 20 percent is dependent upon the loss in weight irrespective of whether the wood was heated in air, nitrogen, or in a closed system. Beyond 20 percent loss in weight, the curves deviate greatly. The antishrink efficiency obtained by heating in the bomb continues to increase with increasing weight loss. The antishrink efficiency obtained by heating in nitrogen remains virtually constant, and the antishrink efficiency obtained by heating in air decreases for weight losses exceeding 20 percent. A similar relationship holds for the relative hygroscopicity at 90 percent relative humidity. The fact that relatively large

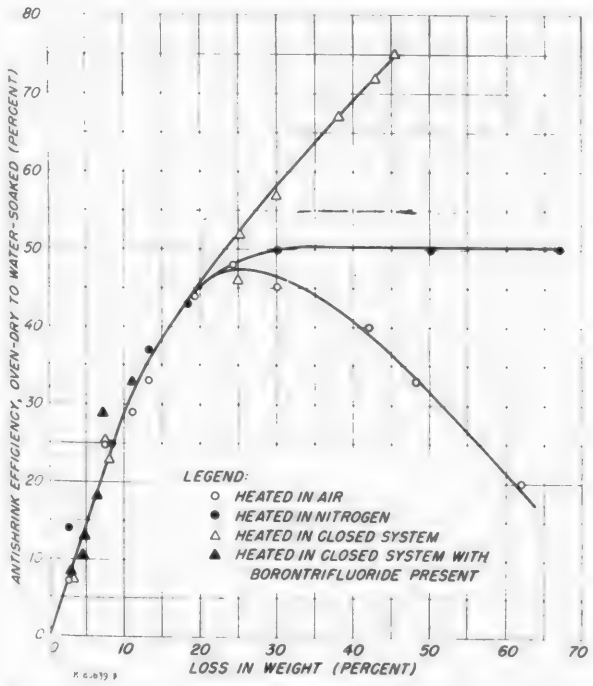

ANTISHRINK EFFIGIENCY, OVEN-DRY TO WATER-SOAKED (PERCENT)
LEGEND:
HEATED IN AIR
HEATED IN NITROGEN
HEATED IN CLOSED SYSTEM
HEATED IN CLOSED SYSTEM WITH BORONTRIFLUORIDE PRESENT
LOSS IN WEIGHT (PERCENT)

Figure 6.—Relation of antishrink efficiency resulting from heating the dry specimens of figures 1 to 5 to the weight loss.

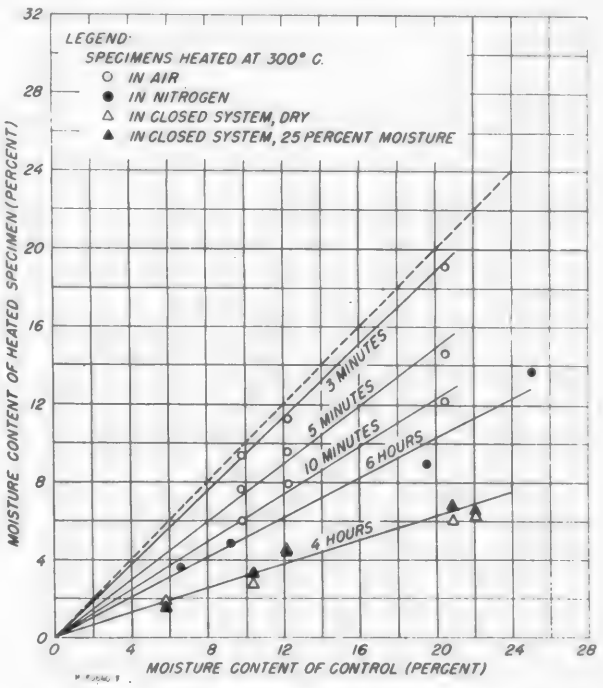


Figure 7.—Relation of equilibrium moisture content of specimens heated under different conditions at 300° C. for different periods of time to the equilibrium moisture content of the control specimens, which had been exposed to the same relative humidities as the heated specimens.

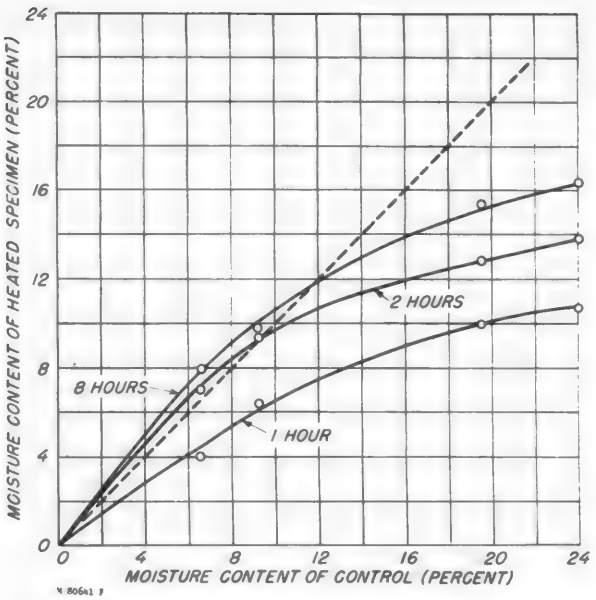


Figure 8.—Relation of equilibrium moisture content of specimens heated for 1 to 8 hours in air at 300° C. to the equilibrium moisture content of the control specimens, which had been exposed to the same relative humidities as the heated specimens.

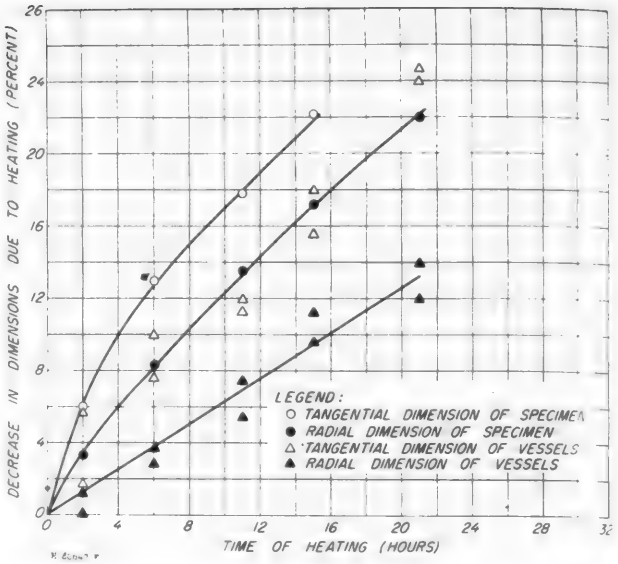


Figure 9.—Effect of heating 30-micron cross sections of sugar maple in air at 206° C. for different periods of time upon the subsequent specimen and vessel dimensions measured at 20 percent relative humidity.

weight losses are required to obtain appreciable reductions in hygroscopicity supports the view that cross linking is not responsible for stabilization of wood by heat treatment.

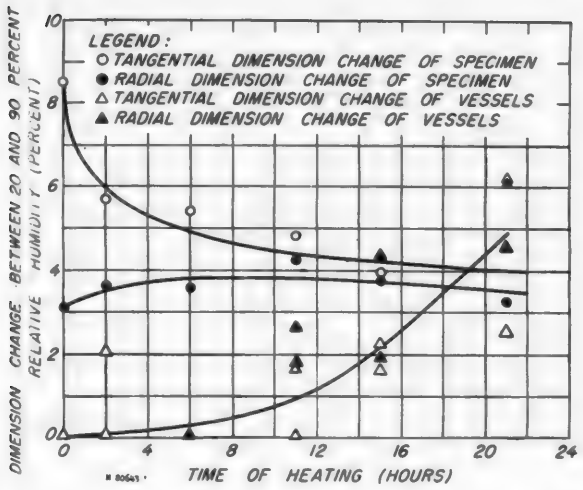
Figure 7 gives a plot of the equilibrium moisture content of the heated specimens against those of the controls under the same exposure conditions. The data given in this figure in all cases are fairly well represented by straight lines through the origin. This means that the relative hygroscopicity (moisture content of the heated specimen divided by that of the control) is practically independent of the exposure conditions. This is usually true for all woods stabilized by resin treatments *(10)* and by acetylation *(11)*. Antishrink efficiencies are also virtually independent of the exposure conditions for dimensionally stabilized woods produced by any of the three methods.

Figure 8 shows that in the case of wood heated in air for periods of time such that the loss in weight exceeds 20 percent (fig. 6), the relationships of figure 7 no longer hold. The curves are not only displaced upwards with increasing time of heating instead of being displaced downwards, but distinct curves rather than straight lines are obtained. For low moisture contents, the relative hygroscopicity is actually increased for wood heated for 2 hours or more at 300° C. The relative hygroscopicity, however, decreases appreciably with increasing moisture content.

Internal Dimension Changes

On comparing the decrease in dimensions with the decrease in weight (figs. 1 to 3), it should be kept in mind that the decrease in dimensions refers to that in the radial direction. It would be more appropriate to compare the percentage decrease in weight with the percentage decrease in volume. Since dimension changes in the radial direction are about half of the values in the tangential direction for the ponderosa pine wood, and since changes in the longitudinal direction can be neglected, the weight changes in figures 1, 2, and 3 should be compared with values corresponding to about 3 times the radial change. The percentage volumetric change is approximately equal to the sum of the percentage change in the tangential direction and the radial direction. If the tangential change is assumed to be twice the radial change, the volumetric change is 3 times the radial change. It will be noted now that on this basis the weight changes and volume changes are of the same order of magnitude. Thus, according to figure 1, after heating at 300° C. for 30, 60, and 120 minutes, the weight changes are 30, 41, and 53 percent, respectively, and the volume changes are 20, 33, and 51 percent, respectively. Such large volume changes are surprising. On drying wood, the percentage volume change is generally less than 50 percent that of the percentage weight change. If it is assumed that additional voids are created on heating wood, then the corresponding external volume change would be expected to be a small fraction of the weight change. It must be assumed, then, that in addition to a loss of volume due to the removal of wood substance, there occurs a decrease in volume of the cell cavities, which decrease is transmitted to the external volume of the wood.

To check this, microscopic observations were made of 30-micron-thick cross sections of alpine fir, maple, and ailanthus. The latter species was chosen because of its large, easily measurable vessels. Selected cell cavities were measured before and after heat treatment. The specimens were mounted in a special microscope cell through which humidified air was passed. The specimens were first conditioned at 20 percent relative humidity, following which the tangential and the radial dimensions of each whole specimen between marked points, the tangential and the radial dimensions of several marked vessels of the hardwoods, and of several marked lumina of tracheids of the softwood were measured with an ocular micrometer. The specimens were then conditioned at 90 percent relative humidity, measured, and again conditioned at 20 percent relative humidity and measured. The sections were placed between pieces of platinum gauze to keep them flat and were heated in a jacketed tube (Abderhalden flask) with nitrobenzene vapors (206° C.) for various periods of time. After cooling, they were again placed in the microscope cell and taken through a 20 to 90 percent relative humidity cycle to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DIMENSION CHANGE BETWEEN 20 AND 90 PERCENT RELATIVE HUMIDITY (PERCENT)
TIME OF HEATING (HOURS)

Figure 10.—Effect of heating 30-micron cross sections of sugar maple at 206° C. for different periods of time upon the subsequent dimension changes of the specimen and of the vessels between 20 and 90 percent relative humidity.

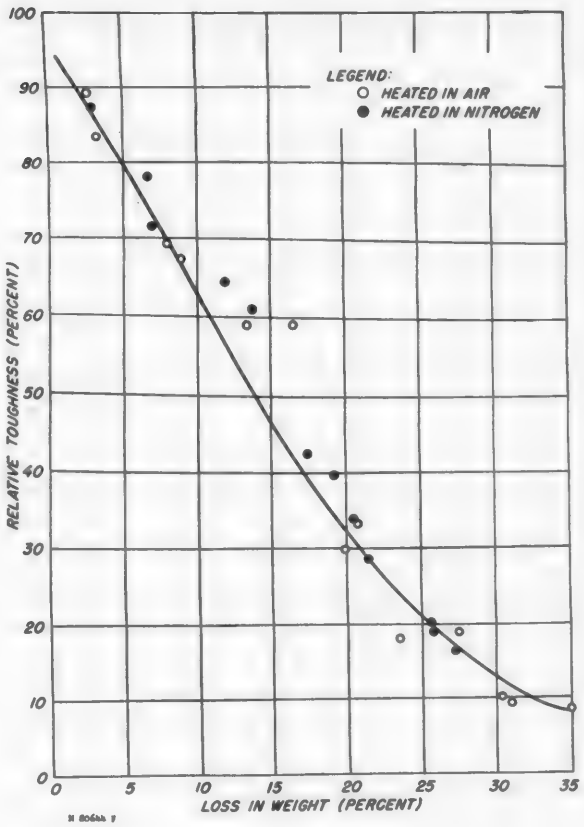

Figure 11.—Relationship between relative toughness (ASTM method) and weight loss for ponderosa pine sapwood cross sections that were heated at 300° C.

release thermal stresses resulting from heating. The specimens were then measured while at equilibrium with 20 percent and 90 percent relative humidity.

Figure 9 gives the dimension changes of sugar maple heated in air at 206° C. for different periods of time. The vessels show a definite decrease in diameter due to heating, which is somewhat less than for the specimens as a whole. The same is qualitatively true for the lumina of the softwood specimens, which, because of their smaller size, could not be measured with as great accuracy. Thus the cell cavities do decrease in size on heating. The externally observed decrease in volume must be due to both a removal of wood substance from the cell walls and to the decrease in volume of the cell cavities. It is not very likely that additional void volume is created in the cell walls.

The experiment was repeated with the cross sections heated after thorough evacuation with a high vacuum pump. For a given period of heating, these specimens did not darken as much as did the specimens heated in the presence of air. The decrease in tangential dimension of both the whole specimen and of the cell elements was less than that of the specimens heated in the presence of air; however, the ratio of the decrease in tangential dimension of the whole specimen to that of the cell cavities was approximately independent of whether the specimen was heated in the presence or absence of air. Had the heat treatment of the evacuated specimen been continued until it had darkened to the same degree as the specimen heated in air (that is, until the weight losses were the same), the reductions in dimensions of the whole wood and of the cell cavities would very likely have been the same as those of the wood heated in air.

Figure 10 shows the dimension changes of the maple specimens as a whole and of the vessels between 20 and 90 percent relative humidity for unheated specimens and specimens heated for several different periods of time at 206° C. Heating up to 10 hours had but a slight effect upon the subsequent change in dimensions of the vessels, whereas continued heating caused larger relative dimension changes than occurred in the specimens as a whole.

Different pores do not change dimensions by the same amount. Pores nearest to the annual rings, in general, change more than those somewhat removed from the annual rings. This same phenomenon has been observed for the lumina of unheated wood *(1, 5)*, in which case stresses caused by different swelling tendencies of the different zones within the annual ring cause individual lumina to respond differently, even though statistically they do not change significantly in size with swelling and shrinking of the wood.

Similar results were obtained with other samples of sugar maple and with ailanthus.

Dimension changes for the lumina of the softwood, because of their smaller size, could not be followed as accurately as the dimension changes of the vessels. Qualitatively, however, the results appear to be similar.

It is thus apparent that with variations in relative humidity, not only is the corresponding dimension change of the cavities in unheated wood small, but it is also small for cavities in mildly heated wood. With prolonged heating, however, the dimension changes of the cell cavities become pronounced with variations in relative humidity. Perhaps this accounts for the peculiar behavior of the relative swelling curve in figure 1. After mild heating, the cell cavities do not change in size on exposing the wood to different relative humidities. In such wood, the reduced swelling tendency is due to the reduced hygroscopicity of the wood substance. With prolonged heating, some of the restraints to dimension change of the cell cavities are removed. Although the swelling tendency of the wood substance is reduced, this is more than compensated for by the pronounced

Table 3.--Effect of heating wood in molten metal upon the abrasive wear and hardness modulus

Species	Temperature	Time	Approximate anti-shrink efficiency	Wear due to abrasion[1]	Hardness modulus (14)
	° C.	Min.	Percent	Inches per 1,000 revolutions	P.s.i.
Douglas-fir		0	0	0.05	2,580
Do	250	3	20	.06	2,730
Do	300	3	40	.09	2,520
Yellow birch		0	0	.02	5,450
Do	250	3	20	.05	5,720
Do	300	3	40	.07	5,310

[1] Measurements made on Navy abrader (2).

Table 4.--Effect of heating basswood in air and in a bomb with steam upon the abrasive wear

Heating medium	Temperature	Time	Approximate anti-shrink efficiency	Wear due to abrasion[1]
	° C.	Min.	Percent	Inches per 1,000 revolutions
		0	0	0.10
Air	300	10	45	.29
Do	300	20	50	.42
Do	300	60	40	.78
Steam	193	5	10	.22
Do	193	30	15	.18
Do	193	240	20	.21

[1] Measurements made on Navy abrader (2).

increase in dimensions of the cell elements during swelling. This increase in dimensions of the cell cavities is transmitted to the external dimensions and is reflected in an increase in relative swelling. The swelling of severely heated wood is comparable to the swelling of a film of gelatin having a hole in it. The hole gets larger during swelling, as do the cell cavities during swelling of the wood. No explanation can be offered for the difference in behavior of the relative swelling curves for wood heated in air (fig. 1) and for wood heated in nitrogen (fig. 2).

A few tests were made, while it was still thought that the loss of water caused ether cross bridges to form between cellulose chains, to see if boron trifluoride added to the sealed bombs in which wood was heated, might catalyze the desired reaction. The data in figure 6[4] show that the same anti-shrink efficiency is obtained per unit weight loss as for the controls, even though the rate of loss of weight was accelerated. There is thus no advantage in adding boron trifluoride.

[4] Thanks are due to Dr. M. A. Millett for obtaining these data.

Effect of Heat Upon the Toughness and Abrasion Resistance of Wood

Figure 11 gives the relative toughness (ASTM method) versus the weight loss for wood heated at 300° C. for various periods of time. It shows that there is no significant difference in the results obtained by heating in air and by heating in nitrogen. Specimens heated in air, in nitrogen, and in sealed bombs so as to give weight losses significantly greater than those at which the curves of figure 6 diverge, became so brittle that they were difficult to handle without break-

ing. Hence no measurements were made on such specimens.

Wood heated so as to attain a practical antishrink efficiency, between 28 and 45 percent, undergoes a weight loss of 10 to 20 percent (fig. 6). This corresponds to relative toughness values of 63 to 32 percent. As in the case of formaldehyde-treated wood *(12)*, the toughness loss is, however, presumably due to a break-down of the cellulose chains rather than to a stiffening of the fiber.

This type of embrittlement is much more serious than that caused by stiffening of the fibers by resin treatment *(3)*, as is shown by the loss in abrasion resistance. Tables 3 and 4 show that wear under abrasive action increases greatly on heating. Wood that gives an antishrink efficiency of 40 percent on heating abrades 1.8 to 3.5 times as readily as the unheated wood. In contrast, resin treatment causes only a slightly greater rate of wear under abrasion conditions than that for the untreated wood.

Table 3 also gives values for the modulus of hardness *(14)*. The hardness is at first increased somewhat on heating. Very little loss in hardness occurs even after heating under conditions that give a 40 percent antishrink efficiency. It has been claimed that for normal wood, hardness is a good index of the abrasion resistance. In the case of heated wood this statement is far from true.

It has been previously shown that the modulus of rupture and modulus of elasticity in bending are not seriously reduced when wood is heated to obtain a significant antishrink efficiency *(4, 8)*. Qualitative tests indicate that the shear strength of wood may be as seriously reduced by heating as the toughness and the abrasion resistance. On account of the serious loss in these three properties, it is not probable that stabilizing the dimensions of wood by heating will find many commercial uses, especially as no technique for avoiding the embrittlement and poor abrasion resistance have been found.

Conclusions

It has been shown that the dimensional stabilization of wood caused by heating under more drastic conditions than those used in seasoning is not due to an ether cross-linking reaction, as was earlier supposed.

Data for the heating of both paper and wood in the presence and in the absence of air indicate that air is not needed to cause dimensional stabilization. Up to a weight loss for wood of about 20 percent, the reduced hygroscopicity and dimension changes are dependent upon the weight loss and not upon the medium in which the wood is heated. The presence of air, however, does accelerate other secondary changes, such as changes in strength, and on prolonged heating it causes a reversal in the stabilization.

Antishrink efficiencies exceeding about 45 percent are not obtainable by heating either in air or in nitrogen. Wood heated in nitrogen, unlike that heated in oxygen, maintains this optimum antishrink efficiency on prolonged heating even though the wood continues to lose weight. Higher antishrink efficiencies can be attained by heating in a closed system. For any one temperature, a constant weight loss and antishrink efficiency are rapidly attained, which do not increase with time. Presumably, when the reaction products are not removed from the reacting system, a decomposition equilibrium is attained.

If moisture is present, the same equilibrium values are usually attained at high temperatures as when moisture is absent, but at a more rapid rate, presumably because of the improved heat transfer. At lower temperatures (160° to 205° C.), the presence of moisture in the wood at the time of heating causes the attainment of a lower antishrink efficiency than when the wood is heated in the dry condition. The reason for this is still unknown.

The percentage loss of volume on heating is unusually large. This contraction must be due in part to a reduction in the volume of the cell cavities. Microscopic observations have shown that the cell cavities do decrease in dimensions during heat stabilization. For a given loss of weight, the reduction in size of these cavities seems to be independent of whether heating is done in the presence or absence of air. It is not necessary to assume the formation of submicroscopic voids in the cell walls, since such formation would require that the reduction in size of the cell cavities be greater than is actually observed.

The great loss in toughness and in abrasion resistance and probably in the shear resistance of wood that has been given a significant dimensional stabilization by heating, does not appear to be due to oxidation, but it is inherently associated with the other chemical reactions that cause dimensional stabilization. Unless some way can be found to separate the dimension–stabilizing from the embrittling reactions, which does not seem probable at present, the commercial use of wood stabilized in this way will be quite limited.

Literature Cited

1. Beiser, W. Kolloid Z. 65:203 (1933).
2. Cizek, A. W., Jr., Kallas, D. H., and Nesttem, H. Amer. Soc. Testing Materials Bull. 132 (1945).
3. Erickson, E. C. O. U. S. Forest Products Laboratory Rept. R1639 (1947).
4. MacLean, J. D. U. S. Forest Products Laboratory Rept. R1471 (1945).
5. Schwalbe, C. G., and Beiser, W. Papier–Fabr. 50:655 (1933).
6. Stamm, A. J. U. S. Patent 2,296,316 (1942)
7. ———, "Wood Chemistry," ed. by L. E. Wise, Pt. IV, p. 464, Reinhold Publishing Corp. (1944).
8. ———, Burr, H. K., and Kline, A. A. Ind. Eng. Chem. 38:630 (1946).
9. ———, and Hansen, L. A. Ind. Eng. Chem. 29:831 (1937).
10. ———, and Seborg, R. M. Ind. Eng. Chem. 28:1164 (1936).
11. ———, and Tarkow, H. J. Phys. Colloid Chem. 31:493 (1947).
12. Tarkow, H. and Stamm, A. J. Forest Products Research Soc. V. 3: No. 2 (1953).
13. Tiemann, H. D. Lumber World Review 28:(7) 10 (1915).
14. Weatherwax, R. C., Erickson, E. C. O., and Stamm, A. J. Amer. Soc. Testing Materials Bull. 153, 84 (1948).

UNEVEN COATINGS ON WOOD CAUSE WARPING

Unequal coatings on opposite surfaces of a wood article cause uequal rates of change in moisture content and hence unequal shrinkage on the two sides of the piece. The result is that the wood tends to cup or twist out of shape.

Coatings of nearly equal moisture resistance should be applied to all surfaces of wood products if the tendency to warp under changing atmospheric conditions is to be kept to a minimum. Tests at the Forest Products Laboratory show that no coating applied on wood entirely prevents it from picking up or giving off moisture and, consequently, from swelling and shrinking under the influence of varying atmospheric conditions.

Clear as well as pigmented coatings, regardless of type or composition, merely decrease the rate at which the moisture content changes in wood occur. In general, pigmented coatings, such as paint, are somewhat more effective in retarding moisture changes than clear coatings, such as varnish or shellac, and within practical limits the more coats applied, the slower will be the moisture changes.

Inexpensive coatings can often be applied to the backs of furniture or millwork that will be practically equal in moisture resistance to the coatings on the exposed surfaces. (See Technical Note No. 181 for the relative moisture-excluding effectiveness of some commonly used coatings.)—Tech. Note No. D-12, U. S. Forest Products Lab.

The Regulation of Aeration in Wood Soil Contact Culture Technique[1]

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Need for substantial aeration of wood in the soil-block type of test is emphasized. Attention is also called to the striking effect that a special type of ventilation method employed had in conserving moisture in the test bottles.

Summary

EXPERIENCE WITH THE LEUTRITZ wood-soil contact culture technique at the Vancouver Forest Products Laboratory has not hitherto been uniformly satisfactory. In some cases the amount of decay produced in wood blocks by the same fungus has varied greatly, and in others growth of the inoculum has been slow or entirely inhibited. Search was made therefore for some factor which might have caused these variable results.

The aerobic nature of most wood-destroying fungi requires suitable ventilation within the culture jars to permit passage of the gaseous products accompanying the decay process and for the admission of air. The amount of decay produced in each of a series of tests in which wood blocks were exposed to cultures of wood-destroying fungi in soil jars was more constant when such aeration was supplied by means of glass vent tubes in the lids than when the jars were covered by loose screw caps. Wide variation in fungal activity and subsequent rot development in the blocks occurred in culture jars when ventilation was restricted by the use of tight screw caps. Where rubber stoppers were used, growth of the fungus was soon entirely inhibited.

By incorporating a glass vent-tube in the lids of soil culture jars to standardize the allowed space for gaseous interchange during decay of wood test specimens, variations in fungal activity attributable to this factor may be minimized and the findings of various workers employing this technique more readily compared.

Introduction

At the present time, in spite of its obvious desirability, no universally accepted or standardized method exists by means of which accelerated decay resistance of wood, untreated or treated with preservatives, may be investigated in the laboratory. In this connection, the Leutritz[2] wood-soil contact culture technique for accelerating decay in laboratory specimens of wood has attracted favourable attention of recent years and has been employed in a number of institutions, so that it has promised to fill the need for a standard method.

Briefly, the technique consists of exposing wood blocks to pure cultures of decay organisms growing upon moist wood and top soil, contained in closed glass jars held in incubators, with the resultant loss in weight of the test blocks being taken as a measure of their resistance to the fungus involved. The chief advantages over the use of a nutrient agar substratum such as has been widely used by European investigators are that the damp soil renders available a constant source of moisture, and the use of sapwood feeder strips provides a natural food supply for the test fungi.

While the requisite apparatus is simple and apparently easy to reproduce in a series, variations in results have been reported from various laboratories. This also was the experience at the Vancouver Forest Products Laboratory where, in several test series, good initial growth of the inoculum was usually attained but with accompanying wide variation in the weight losses caused by identical fungi. There was also variation in the final moisture contents of the blocks and of the soil substratum, at the end of the exposure period.

Searching for some basic cause of these irregularities, it seemed likely that erratic aeration of the jars was responsible. As had been done elsewhere, the jar caps or lids had been screwed down "finger-tight", but little attention had been paid to the

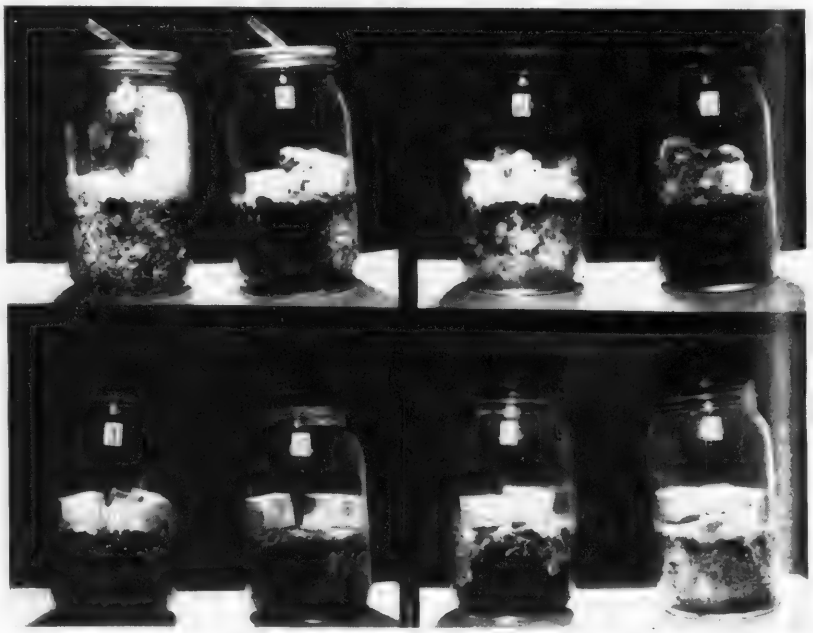

Figure 1.—Comparative fungal growth resulting from controlled ventilation in culture jars containing wood-destroying fungi, Poria monticola (jars 1 to 4) and Lenzites trabea (jars 5 to 8). Jars numbered 1 and 5 are covered with vented caps; jars 2 and 6 are covered with loose screw caps; jars 3 and 7 are tightly capped and jars 4 and 8 are stoppered with sealed, rubber corks. NOTE: Mycelial growth which is evident within the soil substrate in each jar developed during the initial incubation period before aeration was controlled.

[1] Contribution from the Vancouver Laboratory of the Forest Products Laboratories Division, Forestry Branch, Department of Resources and Development, Canada.

[2] Leutritz, John Jr., Bell System Technical Journal, Vol. 25, No. 1, pp. 102–135, Jan. 1946.

condition of the paper seal provided with each cap. It was thought, therefore, that some air was admitted as a result of incomplete sealing, but that the amount varied as between jars, resulting in erratic metabolism and erratic growth of the decay-producing fungus.

Experiments were then set up to investigate the effect of various degrees of aeration on fungal growth in soil jars, and to see if, by regulating the amount of aeration, fluctuations in results within a series might be eliminated.

Experimental Procedure

Garden top soil (pH 5.5) from a greenhouse was air-dried and sifted through a coarse screen. Sufficient tap water was added to the dry soil to bring the moisture content up to approximately 35 per cent and the mixture placed in a ball mill for one-half hour to ensure uniformity. Approximately 250 grams of moist soil were then placed in each of 32 wide-mouthed glass jars (8 x 14 cm.) with screw tops. The soil was lightly packed and levelled; two thin feeder strips of sapwood, one of western white pine (2 x 6 x 0.25 cm.) and the other western hemlock (2 x 3 x 0.25 cm.) were placed upon the soil in each jar, the caps screwed on without sealing, and the whole steam-sterilized for one-half hour at 15 pounds pressure.

After cooling, the jars were removed and inoculated in a sterile culture room with a wood-destroying fungi—*Lenzites trabea* or *Poria monticola*—a small square of inoculum being cut from a two weeks old culture of the organism and placed upon each of the feeder strips so that an equal number of jars contained pure cultures of each organism. The caps were replaced without sealing and the jars placed in laboratory incubators at 80 ° F. for one month, when active fungal growth was evident upon all strips.

Each jar had been weighed empty, also after insertion of the soil and wood strips, before and after sterilization, and after one month's preliminary incubation. The loss of moisture from the jars during the sterilization process averaged three per cent of the original total weight, while during the initial incubation period there was a further loss of two per cent of the original weight. The moisture content of the soil mixture at the outset of the test period was therefore approximately 30 per cent, based upon the original dry weight of the soil.

Blocks used for the test were western white pine and western hemlock sapwood, free from visible defect, cut into cubes, approximately 2 square centimetres on each face, numbered consecutively, and conditioned to an equilibrium moisture content for four weeks previous to the test. Conditioning was done in a laboratory apparatus in which a humidified stream of air was drawn by means of water suction through a saturated salt solution and passed over the blocks, which rested upon wire mesh in an enclosed chamber. The solute employed was sodium chloride, which maintained a relative humidity, at room temperature, of 76 per cent (the slight variations in temperature maintained this figure within 2 per cent[3]) and resulted in an equilibrium moisture content which averaged 13 per cent for all blocks in the test.

After conditioning, each block was weighed, then held with a needle in a jet of steam. It was then surface sterilized and placed in one of the inoculated jars, each block resting upon a sapwood strip of the same species so that each jar held three blocks, two of western white pine and one of western hemlock.

The jars were capped by four different methods:

a. Eight jars stoppered with No. 12 rubber corks cemented to the glass by means of a plastic solution.
b. Eight jars covered with screw caps containing fresh oiled papered liners and tightened forcibly by hand.
c. Eight jars closed in a similar manner to method (b) but after screwing down each lid was loosened one-half turn (180 degrees).
d. Eight jars closed with vented caps. These caps were prepared from Bernardin No. 63 domestic type two-piece lids, consisting of a thin circular metal plate and an outer knurled ring. A strip of rubber is attached to the circular plate, which seals the circumference of the jar mouth

[3] Hopp, Henry. Control of atmospheric humidity in culture studies. Bot. Gaz. Vol. 98, 12 pp., 1936.

TABLE I

Decay losses observed after 4 months' exposure of 16 western white pine and 8 western hemlock blocks to wood-destroying fungi in ventilated wood-soil contact culture jars

Jars covered with a vented cap*			Jars covered with a loose screw cap**		
Block No.	Wood Species	Loss due to decay based on original wt.(per cent)	Block No.	Wood Species	Loss due to decay based on original wt.(per cent)
27	w.w.pine	61.7	15	w.w.pine	63.5
28	"	62.8	16	"	63.6
29	"	64.1	17	"	64.8
30	"	65.1	18	"	64.7
31	"	63.4	74	"	49.4
32	"	62.6	75	"	63.7
92	"	53.6	72	"	60.8
93	"	58.6	73	"	63.3
91	"	64.9	79	"	62.2
84	"	66.1	82	"	58.4
94	"	65.2	78	"	64.4
96	"	60.7	81	"	56.0
95	"	56.1	76	"	61.8
97	"	64.8	77	"	47.1
134	"	60.0	120	"	58.5
135	"	59.9	121	"	75.6
46	w.hemlock	60.4	40	w.hemlock	59.8
47	"	60.7	41	"	60.4
48	"	60.4	106	"	55.0
115	"	59.0	105	"	57.6
114	"	57.2	109	"	61.9
116	"	60.0	108	"	57.7
117	"	54.0	107	"	63.5
145	"	65.6	139	"	49.0
AVERAGE		61.1	AVERAGE		60.1
Range +5.0 to -7.5			Range +15.5 to -13.0		

*A 6 mm. glass tube inserted in the central plate of a Bernardin No. 63 2-piece metal lid, sealed to the jar.

**The metal screw cap containing an oiled paper liner, was screwed tight, then released one-half turn.

when the outer ring is screwed down. A hole was drilled through the circular plate to admit a short 6 mm. (O.D.) glass tube set at an angle of 45 degrees and sealed to the plate with de-Khotinsky cement (see plate 1). As the cement becomes liquid at high temperatures, these caps were sterilized in boiling water for 3 minutes before placing upon the jars.

After closing, the jars were placed in laboratory incubators at 80° F. for four months. At the end of the exposure period the total jar weight was recorded, the blocks removed, and after brushing off the fungous matter, were immediately weighed, then placed in the constant humidity chamber for conditioning, after which they were re-weighed, oven-dried and finally weighed again.

Results

Wood Decay: Although two species of fungi were used in the test, *Lenzites trabea* and *Poria monticola,* as well as two wood species, western white pine and western hemlock, results were comparable in all culture jars throughout the four series. Decay developed rapidly in the wood blocks contained in those jars where aeration had been allowed, whereas in the closed jars decay processes had been either completely inhibited or had proceeded spasmodically (Tables 1 and 2).

The measure of fungal activity, i.e., the loss of wood weight due to decay in the blocks, was more constant in the vented jars than in those which were loosely capped. While the average decay figure was only slightly higher in the former instance—61.1 per cent of the original conditioned weight as compared with 60.1 per cent for the latter—the range of individual weight losses in the former series was much less, the values lying within +5.0 and -7.5 of the average for the blocks in vented jars as compared with a range of +15.5 to -13.0 of the average for those in the loosely capped jars.

Considerable variation in fungal activity was noted in the 8 jars which remained tightly closed with screw caps. In 4 of these jars, decay appeared completely inhibited, and no loss in weight was noted in any of the blocks contained in them. The remainder of the series exhibited fungal growth varying from vigorous to weak, and decay losses in the included blocks ranged from 67.7 per cent to 2.2 per cent of the original conditioned weight.

TABLE 2

Decay losses observed after 4 months' exposure of 16 western white pine and 8 western hemlock blocks to wood-destroying fungi in unventilated wood-soil contact culture jars*

Jars tightly covered with a screw cap**			
Block No.	Wood Species	Loss due to decay based on original wt.(per cent)	
5	w.w.pine	Nil	
6	"	"	
7	"	"	
8	"	"	
70	"	67.7	*No decay losses were noted in blocks inoculated with decay fungi and contained in jars closed with rubber stoppers.
71	"	65.7	
66	"	66.4	
68	"	66.4	
64	"	Nil	
65	"	"	
62	"	"	
63	"	"	
126	"	2.9	
127	"	2.2	
128	"	2.9	
129	"	8.0	
35	w.hemlock	Nil	
36	"	"	
104	"	67.7	
102	"	64.2	
101	"	Nil	
100	"	"	
141	"	24.0	
142	"	53.1	
	AVERAGE	Erratic	

**The metal screw cap containing an oiled paper liner was screwed down forcibly.

TABLE 3

Loss in total wood-soil weight from jars containing cultures of wood-destroying fungi closed by various methods over a 4-month test period

Jars covered with vented caps*		Jars covered with loose screw caps*		Jars tightly covered with screw caps*		Jars sealed with rubber stoppers	
Jar No.	Wt. loss Per cent	Jar No.	Wt. loss Per cent	Jar No.	Wt. loss Per cent	Jar No.	Wt. loss Per cent
18	1.3	13	11.4	11	2.5	15	Less than 0.1
19	0.6	14	10.0	12	2.9	16	" "
20	0.6	25	11.8	27	4.2	17	" "
21	0.6	26	10.8	28	6.1	23	" "
22	1.3	34	9.6	33	4.1	24	" "
29	1.2	35	11.1	38	3.2	32	" "
30	1.0	36	11.7	45	4.3	42	0.2
47	0.9	41	9.1	46	3.4	43	Less than 0.1
Average	0.9	Average	10.7	Average	3.8		---
Range	+0.4 to -0.3	Range	+1.8 to -1.6	Range	+2.3 to -1.3		---

*See footnote Tables 1 and 2.

Decay was uniformly inhibited in all jars closed by means of rubber stoppers and no weight loss was encountered in any of the wood blocks in this series.

Moisture Behaviour: The moisture contents of each block were computed immediately after four months' exposure to decay, also the loss in total weight over the period for the contents of each jar. While in regard to moisture movement the blocks themselves indicated inconclusive results, pertinent information was revealed by considering the total wood-soil combination.

In recording the final total weight of each jar after the test period and comparing these with the original figures, significant trends were noted between the three series which comprised those jars closed with screw-type caps. In the jars equipped with the vent tubes, only 0.9 per cent of the original total moist soil-wood weight was lost over the four-month period; those with the loosened caps averaged 10.7 per cent loss, while the tightly capped jars lost an average of 3.8 per cent of this original weight. The range of weight losses for all jars in each series was least in the vented jars, being +0.4 and —0.3 in relation to the average; in the loosely capped jars the range was from +1.8 to —1.6 and in the tightly capped series it was +2.3 to —1.3. In jars of the latter series, where decay activity was spasmodic, no significant changes in weight were observed to accompany these variations (Table 3).

In the case of the rubber-stoppered jars, insignificant losses occurred amounting to less than 0.2 per cent of the original total weight, probably attributable in part to the evaporation of the volatile solvent from the rubber cement outside the stopper.

A wide variation was noted between the individual percentage moisture contents, determined after the four month's exposure, of all blocks in each series and the figure was never constant for any set of three blocks contained in one jar. The highest values were obtained in the vented jars and averaged 82.3 per cent of the final oven-dry weight for all blocks in this series as compared with 56.3 per cent in the loosely capped jars and 49.0 per cent and 40.7 per cent in the tight capped and sealed jars respectively. No correlation was apparent between the absolute values of final moisture content and percentage weight loss caused by decay.

Discussion

It is emphasized that the limited number of soil jars used did not permit an intensive statistical analysis of the results. However, these are sufficiently uniform in regard to, first, the amount of decay in different jars and in different blocks in the same jar, and secondly, maintenance of a satisfactory moisture control in the substrate, to be indicative.

Averaging of decay losses resulting from two different wood-destroying fungi is not a procedure to be recommended in routine tests, because there may be variation in their aeration requirements; but the two fungi used, *Lenzites trabea* and *Poria monticola,* demonstrated similar aeration requirements. Also, they both produce brown rots, and the decay losses were so nearly alike in both cases that the figures were averaged.

The small cubes of wood used for exposure to the fungi were, within each wood species, cut from the same annual rings in the same piece of wood, but no actual measurements of specific gravity or density were made. In the practical application of the technique to a large test series, it is important that the small test blocks should be as uniform in nature as possible, should be cut from the same portion of the tree, should be end matched, and should have a uniform density.

Some workers use oven-dried blocks. One of the objections to this method is that internal stresses are likely to be set up during the oven-drying process, consequently making cavities within the wood. Then there is a possibility that a certain amount of the resins and similar bodies which have a close relationship with durability might be lost in the drying process. In the case of treated specimens, e.g., with creosote mixtures, initial oven-drying becomes very inadvisable, not only for the above reasons, but also because it creates a pre-treating condition never found in actual practice. A standard conditioning to an approximate pre-determined moisture content would appear to be preferable.

The advantages of the vented jar in conserving moisture, as against the jar with the loosened cap, are demonstrated in Table 3. These advantages might be due to the fact that the vent tube provides a greater ventilating effect and has a greater ventilating area. However, this is not necessarily so, and the causes of these differences need to be examined further.

Postulating that decay is an oxidation process, the reaction may be considered as starting with an intake of oxygen and ending with the production of carbon dioxide and water. Since in this study the loss in wood weight due to decay was, in general, comparable for both series (vent-capped and loose screw-capped jars) it is assumed that the oxygen-carbon dioxide movement is similar for both methods of closure. Moisture behaviour, however, is obviously different.

Within each cultural jar, decay or oxidation releases energy in the form of heat, producing convection currents (carrying water in vapour form) which travel upward, strike the jar lid, turn horizontally across the lid to the rim, then return down the glass sides. If some space were allowed around the rim of loose-capped jars, we assume that there would be a greater escape of water vapour this way than through a small central vent in the cap, especially since this passage is not vertical, but is canted at an angle of 45 degrees. As the convection currents return down the side, the water vapour condenses and the liquid returns to the soil. That there are two sets of conditions is indicated by the fact that there was an actual increase in the moisture of the soil-wood combination over a 4-months period in the case of the vented jars but a decrease in the case of the loose-capped jars.

These reactions are indicated in the following summary:

	Vented cap jars—(8 jars; 24 blocks)	Loose cap jars—(8 jars; 24 blocks)
Average loss in total weight of culture jars, moist soil, feeder strips and test blocks, over a period of four months	2.47 gms.	27.86 gms.
Average weight of wood material lost from decay in blocks within jars	5.74 gms.	5.40 gms.
DIFFERENCE: Average moisture content change within jars*	3.27 gms. (decrease)	22.46 gms. (decrease)

*There is a slight inaccuracy in figuring here, since allowance has not been made for the loss in weight of the feeder strips due to decay. As each strip was already partly decayed at the time the original weights were recorded—that is, when the test blocks were placed in the jars—subsequent decay loss may be considered to be less than 0.25 gram per strip.

A further advantage of the vented jar over the jar with the loosened lid is that the lid of the latter, if kept within a humidified chamber (a common practice) may rust to an extent that may block the passage of gases. Furthermore, it is most difficult to loosen all lids in a series to exactly the same extent, because of the limitations of manual adjustment and of possible flaws in manufacture.

Conclusions

The action of most fungi which decay wood is accompanied by inter-

(Continued on page 94)

Treatment of Bilgewater to Control Decay in the Bilge Area of Wooden Boats[1]

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Description of various tests are given to determine which chemicals would be most practical for inclusion in bilgewater to control decay. Requirements other than protection were that chemicals should not otherwise deteriorate the wood, that they be non-corrosive to metal, they not have objectionable odor. Orthophenylphenol and pentachlorophenol appeared to meet the tests satisfactorily.

Introduction

FOR boats continually in normal sea water (approximately 3.6 percent salt), decay of wood members below the water line is generally considered not serious. But for boats operating in fresh or only brackish water, and for boats that are hauled out of the water much of the time and therefore get most of their bilgewater from rain, decay below the water line seems to be sufficiently common to warrant measures to reduce it. Conventional practices for reducing hull decay include ventilation of the bilge area, the use of naturally durable wood, and brushing or dipping interior hull parts with a wood preservative. There has been some pressure treatment of certain decay-susceptible members used in naval and fishing-boat construction.

It has been suggested that worthwhile protection of wood in the bilge area might be had in many cases by adding a fungus-inhibiting chemical to the bilge water. The purpose of this study was to find suitable chemicals. The study was made partly in cooperation with the Bureau of Ships, Navy Department.

Procedure

Selection of Chemicals for Trial: Chemicals were chosen for trial on the basis of the following desired characteristics: (1) good fungus-inhibiting capacity, (2) safety in handling with ordinary precautions, (3) non-corrosive to metal fastenings, (4) sufficiently inexpensive to permit replenishment when lost by pumping the bilge, and (5) free from objectionable odor. Certain of the chemicals were not fully satisfactory in all these respects, but they were included because they possessed other meritorious qualities.

A chemical to be used in bilgewater should not, of course, impair the strength of wood. Moreover, it preferably should not react with the natural preservatives in the wood and lower their protective value; such an adverse effect would be inconsequential as long as the chemical is present, but it conceivably would favor decay of normally resistant wood should treatment of the bilgewater be discontinued. At the outset the character of the chemicals in these respects was not known but was ascertained in the course of the study.

Testing of Fungus-Inhibiting Quality of the Chemicals: The fungistatic or preservative quality of the chemicals was ascertained for solutions in concentrations considered most suitable for maintenance in bilgewater. Two criteria of fungistatic potency were used: (1) the decay resistance imparted to wood blocks by impregnation with the solutions, and (2) the retardation of growth of wood-attacking fungi by the solutions in Petri-dish toxicity tests.

The tests on impregnated wood were made by exposing the treated blocks, after conditioning them to an air-dry state, to decay fungi growing in pure culture. The amount of decay occurring in each block was measured by the loss in dry weight of wood during the period of incubation. This was usually 2 months. The soil-block method of testing was used, the essential features of which have been described[2]. In treating the blocks, the solutions were introduced with the aid of a partial vacuum until the wood was completely saturated. Following impregnation, some of the blocks were left in the treating solution for various lengths of time up to 8 months. The solution temperature during the soaking period was 122 ° F.

The blocks in two series of tests consisted of heartwood of white oak, Honduran mahogany, baldcypress, and Atlantic white cedar. These woods were chosen because of their common usage in boats and their substantial natural decay resistance. In each case the block size was 1-1/32 by 3/4 by 3/8 inch, the shortest dimensions being along the grain. The blocks in a third series of tests were of southern pine sapwood, which has very little decay resistance. The size of the pine blocks was 3/4 by 3/4 by 3/4 inch.

The Petri-dish toxicity tests were made essentially in the manner described by Schmitz[3]. Malt extract (2.5 percent) for nourishment of the test fungi, was added to the solutions, together with enough agar (1.5 percent) to harden the mixture. The fungi were transplanted to the substrate thus formed, and the growth-inhibiting concentrations of a chemical for a particular fungus were shown by the presence or absence of growth in the following two weeks. If a transplant did not grow, it was placed on plain malt agar medium to ascertain whether the fungus had been killed.

Fungi used in the tests on blocks were, with the exception of the first one listed, species that have been found in decayed portions of wooden boats[4]. These were: *Fomes pinicola* (F.P. 15348–S), *Fomes roseus* (Madison 701), *Lenzites trabea* (Madison 617), *Polyporus versicolor* (F.P. 72074), *Poria monticola* (Madison 698), and *Stereum frustulosum* (F.P. 56461–R). Three different fungi were used with each species of wood, choice

[1] In cooperation with the Forest Products Laboratory, maintained by the Forest Service, U. S. Department of Agriculture, at Madison, Wis., in cooperation with the University of Wisconsin.
Also in cooperation with the Bureau of Ships, Navy Department, on this particular study.

[2] A contributed paper.

[2] Duncan, C. G. and Richards, C. A. 1951. Evaluating wood preservatives by soil-block tests: 4. Creosotes. AWPA Proceedings 47:275–287. 1951.

[3] Schmitz, Henry and others. 1930. A suggested toximetric method for wood preservatives. Analytical Edition, Industrial and Engineering Chemistry, Anal. Ed. 2, 361, October 15, 1930.

[4] Davidson, Ross W., Lombard, Frances F., and Hirt, Ray R. Fungi causing decay in wooden boats. Mycologia 39 (3): 313–327. 1947.

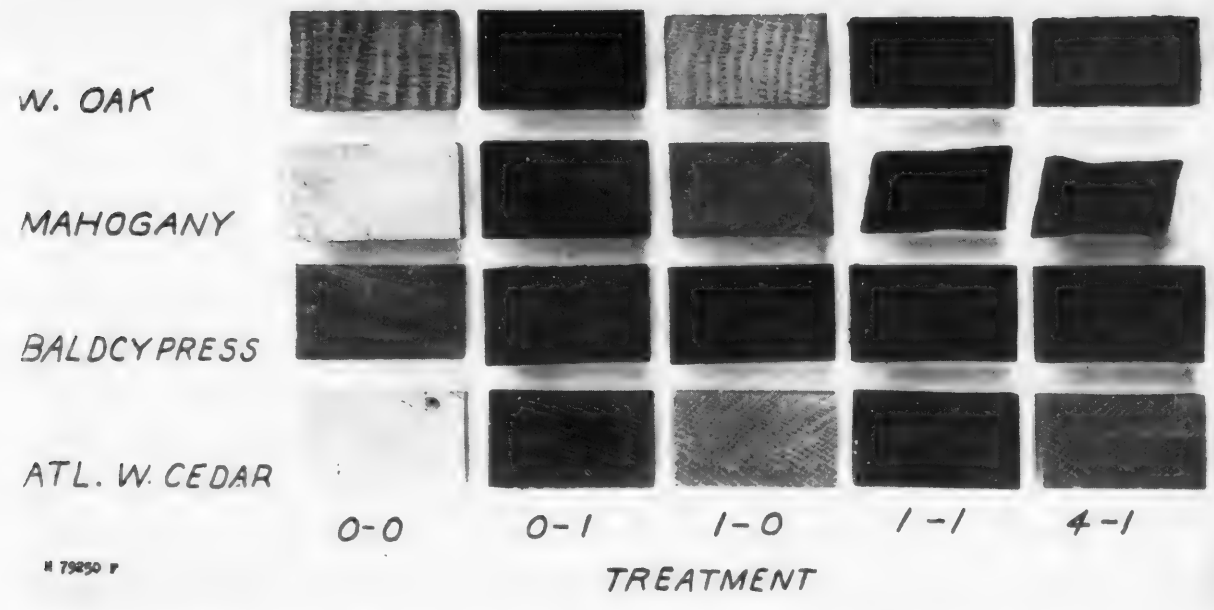

Figure 1.—Representative air-dry blocks of the four wood species that were: untreated (0–0); untreated but leached (0–1); treated with borax solution for 1 month but not leached (1–0); treated with borax solution for 1 month and leached (1–1); and treated with borax solution for 4 months and leached (4–1).

in each case resting on the relative abilities of the fungi to attack the particular wood to be tested. Fungi used in the Petri-dish test were three of the foregoing and an additional decay fungus, *Polyporus tulipiferus* (Madison 517), miscellaneous molds, and a blue stain fungus, *Ceratostomella pilifera* (F.P. 89681). The molds and the blue stain fungus were included because the fundamental interest attached to this phase of the testing made it desirable to consider a representative from all major groups of wood-attacking fungi.

Observations of Chemical Damage to Wood: Tendencies of the chemicals, in the solution strengths employed, to weaken wood were not measured directly; instead, indirect evidence of this was looked for in losses in weight and in abnormal shrinkage of the treated samples prior to their exposure to decay. Either weight loss or shrinkage greater than that resulting from treatment with water alone was regarded as evidence of degradation of wood substance by a chemical.

Tendencies of the chemicals to lower the natural decay resistance of the wood were ascertained by testing the treated blocks after leaching them for 1 month in tap water flowing through the container (¾ gal.) at the rate of approximately 7 gallons per hour. Here also, a chemical could be regarded as deleterious only if the natural decay resistance were reduced more than by similar exposure of the wood to water alone.

Results of Tests of Borax and a Borax-Boric Acid Mixture

Borax and boric acid were the first chemicals considered because they are fungicidal, comparatively inexpensive, and present no problem of odor or handling. The mixture of the two made possible a higher concentration of boron than could be obtained at ordinary temperatures with borax alone and it did not involve the corrosion hazard that would be presented by boric acid alone.

Decay Resistance Imparted to Wood Blocks: Amounts of weight losses caused by decay in untreated test blocks of white oak, mahogany, baldcypress and Atlantic white cedar and in matched blocks that had been impregnated with solutions of borax and of borax plus boric acid are listed in Table 1. The four species of wood were all highly resistant in their natural condition to one or more of the three test fungi used on each. The white oak had high resistance to all three fungi, the mahogany and white cedar to two fungi, and the baldcypress to one fungus. This resistance remained in all woods with the exception of the Atlantic white cedar after the blocks had been leached for a month in running tap water. These results merely characterize the wood used and are not to be considered as representative of the different species.

Treatment with solutions of borax or borax plus boric acid, without subsequent leaching, gave the blocks high resistance to decay by all fungi. Thus the solutions would have sufficient potency for use in bilgewater. One qualifying factor, however, would be the resulting physical damage to tested species of hardwood which will be discussed under "Effect on the Physical Quality of Wood".

Effect on Natural Decay Resistance: Referring again to Table 1, it may be noted that hardwood blocks that were leached after chemical treatment were as resistant to decay by *Stereum frustulosum* and by *Polyporus versicolor* as the comparable unleached blocks. On the other hand, the resistance of the treated and leached blocks of all 4 species to decay by *Poria monticola* was invariably less than the natural amount and also less than in blocks that were correspondingly treated with water alone. It must be concluded, therefore, that the chemicals had promoted the leaching of some of the natural preservatives to which *P. monticola* is particularly sensitive. This influence of the chemicals and the influence of water alone, moreover, appears to have been as large with 1 month of treating as with 4 and 8 months. Smaller and less consistent reductions of natural resistance occurred in the baldcypress and the white cedar against decay by the other fungi.

Effect on the Physical Quality of the Wood: Treated and leached blocks of the hardwood species, particularly the mahogany, showed marked damage by the solutions of borax and borax plus boric acid. This is brought

Table 1.--Weight losses caused by decay in test blocks treated with tap water and with solutions in tap water of borax and of borax plus boric acid, and subsequently leached in some instances[1]

Treating material[2]	Concentration	Treating period	Subsequent leaching period	White oak			Mahogany		
				Weight loss produced by[3]			Weight loss produced by[3]		
				Poria monticola	Stereum frustulosum	Polyporus versicolor	Poria monticola	Stereum frustulosum	Polyporus versicolor
	Percent	Months	Months	Percent	Percent	Percent	Percent	Percent	Percent
None		0	0	5	2	1	25	4	2
None		0	1	7	2	2	30	3	2
Tap water		1	0	4	4	.5	33	4	2
Borax	3.5	1	0	+2	1	.8	.1	2	2
Borax plus boric acid (3 to 2)	5	1	0	+ .2	.2	1	+1	2	.8
Tap water		1	1	23	2	4	27	+ .4	+ .7
Borax	3.5	1	1	38	.8	0	37	1	+2
Borax plus boric acid (3 to 2)	5	1	1	39	.2	.5	40	+2	+2
Tap water		4	1	24	2	7	28	2	+ .2
Borax	3.5	4	1	37	.4	+ .9	38	.6	4
Borax plus boric acid (3 to 2)	5	4	1	40	.3	+3	43	+ .2	2
Tap water		8	1	23	1	7	26	0	1
Borax	3.5	8	1	33	.4	0	38	.6	3
Borax plus boric acid (3 to 2)	5	8	1	41	.8	0	43	.6	+ .6

Treating material[2]	Concentration	Treating period	Subsequent leaching period	Bald cypress			Atlantic white-cedar		
				Weight loss produced by[3]			Weight loss produced by[3]		
				Poria monticola	Fomes roseus	Lenzites trabea	Poria monticola	Fomes roseus	Fomes pinicola
	Percent	Months	Months	Percent	Percent	Percent	Percent	Percent	Percent
None		0	0	11	14	3	31	5	6
None		0	1	19	17	4	37	25	20
Tap water		1	0	17	17	3	37	22	22
Borax	3.5	1	0	+2	1	+1	.6	3	.6
Borax plus boric acid (3 to 2)	5	1	0	1	.7	.1	2	5	2
Tap water		1	1	21	18	3	39	31	27
Borax	3.5	1	1	31	20	3	47	35	23
Borax plus boric acid (3 to 2)	5	1	1	28	19	4	48	37	24
Tap water		4	1	19	12	2	31	40	15
Borax	3.5	4	1	26	27	2	48	46	30
Borax plus boric acid (3 to 2)	5	4	1	32	23	4	46	29	32
Tap water		8	1	23	20	20	40	30	24
Borax	3.5	8	1	32	23	24	46	29	32
Borax plus boric acid (3 to 2)	5	8	1	24	21	30	42	32	39

[1] The test period was 2 months. Values for the treated wood are averages for three blocks; values for the untreated wood are averages for six blocks.

[2] Borax was in hydrated form. The pH's of the treating liquids were approximately: tap water - 7.5, borax - 9.1, and borax plus boric acid - 8.1. Tap water was used in all respects like the chemical solutions as a treating material.

[3] Plus (+) values denote apparent increases in weight.

out in Table 2, by considerably reduced lengths of the chemically treated blocks in contrast to the slight shortening of blocks that were exposed to water only, and likewise by the relatively greater reductions in weight of the chemically treated blocks. Maximum effects in these ways occurred in 4 months of treating. Representative blocks treated for periods of 1 and 4 months are pictured in Figure 1.

The obvious alteration of wood substance in the oak and mahogany would preclude safe use of solutions of borax and of borax with boric acid in bilgewater in contact with wood of a hardwood species.

Results of Tests of Phenyl Mercuric Acetate, Chlor and Phenyl Phenols, and Boric Acid

As solutions containing borax would not be suitable for general use in bilgewater, attention was next directed to boric acid, alone and also in combination with sodium dichromate to prevent corrosion, pentachlorophenol and its sodium salt, trichlorophenol, orthophenyl phenol, and phenyl mercuric acetate. The phenols and phenyl mercuric acetate are extremely powerful fungicides; consequently, they offered considerable promise in spite of their low solubility in water. Moreover, if weak water solutions of these chemicals would inhibit fungus development, the chemicals might be dispensed from bags suspended in the water and thus make the practical problem of maintaining the solutions through changes of bilgewater considerably easier than it would be with a highly soluble chemical. Nylon bags apparently would be sufficiently lasting. Cotton bags containing pentachlorophenol in one trial disintegrated, and othophenylphenol adversely affected rayon in a 7-month exposure. Nylon was unaffected by either of the phenols after 10 months. The sodium salt of pentachlorophenol was included in order to have information about a more water soluble phenol if the members of low solubility did not prove sufficiently effective.

Decay Resistance of Treated Blocks: In testing the second set of chemicals, blocks of the same four kinds of wood were treated. A single treating period of 1 month was used throughout, and the treating was always followed by 1 month of leaching. The decay resistance of the blocks thus treated is indicated by the weight losses shown in Table 3. The chemicals are arranged in increasing order of average weight loss, that is, in decreasing order of decay resistance.

Even though subsequently leached for a month, blocks treated with the

Table 2.--Effect of treatment of test blocks with tap water and with solutions in tap water of borax and of borax plus boric acid on their length and weight when air dry

Treating material[1]	Concentration	Treating period	Subsequent leaching period	Wood			
				White oak	Mahogany	Bald cypress	Atlantic white-cedar
	Percent	Months	Months	Percent	Percent	Percent	Percent
RELATIVE LENGTH (ORIGINAL = 100)[2]							
None		0	0	100	100	100	100
None		0	1	100	100	100	100
Tap water		1	0	100	100	100	100
Borax	3.5	1	0	100	96	100	101
Borax plus boric acid (3 to 2)	5	1	0	100	96	100	101
Tap water		1	1	100	100	99	100
Borax	3.5	1	1	97	82	99	100
Borax plus boric acid (3 to 2)	5	1	1	97	84	99	100
Tap water		4	1	99	99	99	100
Borax	3.5	4	1	96	76	99	99
Borax plus boric acid (3 to 2)	5	4	1	95	77	99	99
Tap water		8	1	99	100	99	100
Borax	3.5	8	1	95	78	99	99
Borax plus boric acid (3 to 2)	5	8	1	95	80	99	99
RELATIVE WEIGHT (ORIGINAL = 100)[2]							
None		0	0	100	100	100	100
None		0	1	99	101	99	99
Tap water		1	0	96	100	99	99
Borax	3.5	1	0	93	101	104	106
Borax plus boric acid (3 to 2)	5	1	0	95	104	106	106
Tap water		1	1	97	99	98	98
Borax	3.5	1	1	92	94	97	96
Borax plus boric acid (3 to 2)	5	1	1	91	94	97	96
Tap water		4	1	96	100	98	98
Borax	3.5	4	1	89	93	96	96
Borax plus boric acid (3 to 2)	5	4	1	89	93	96	97
Tap water		8	1	95	99	96	96
Borax	3.5	8	1	90	92	95	94
Borax plus boric acid (3 to 2)	5	8	1	89	91	96	95

[1]Borax was in hydrated form. The pH's of the treating liquids were approximately: tap water - 7.5, borax - 9.1, and borax plus boric acid - 8.1. Tap water was used in all respects like the chemical solutions as a treating material.

[2]Values for the treated wood are averages for nine blocks; values for the untreated wood are averages for 18 blocks.

phenyl mercuric acetate and with all the phenolic compounds except pentachlorophenol exhibited a high level of resistance to all test fungi. Mahogany, baldcypress, and white cedar blocks treated with pentachlorophenol, which was particularly dilute, and with boric acid were not as well protected against decay by certain of the fungi, primarily *P. monticola.* Nevertheless, these chemicals were highly effective in the white oak and they retained substantial preservative effect in the other woods. Inasmuch as the blocks had been leached, it may be assumed that these preservative qualities were even more pronounced in the wood previous to leaching. The effectiveness of the boric acid was increased by the small addition of sodium dichromate, particularly with the coniferous woods, cypress and cedar; this result is in line with the effect widely attributed to the chromates that they reduce the leaching tendencies of certain water-borne wood preservatives.

In the relative weight losses of blocks treated, respectively, with chemicals and with water, there is no indication that any of the chemicals had reduced the natural decay resistance of the wood significantly more than had water alone. Although the treating period here was only 1 month, it seems probable from indications in the tests with solutions containing borax (Table 1) that longer treating periods would not have altered this situation significantly.

Effect on the Physical Qualities of the Wood: The data of Table 4 were obtained in an attempt to find evidence of damage to the wood, as reflected by reductions in weight and length of the blocks before they were subjected to decay. As already shown (Table 2) the minimum relative length of blocks treated with plain water for a month and leached was 99 and the minimum relative weight was 97. With these values as points of reference for zero effect, no significant damage to the wood by the chemicals listed in Table 4 is indicated except, possibly, for boric acid. The slightly smaller relative weights of some groups of the boric acid treated blocks suggest mild action by the acid, but as there was no apparent accompanying reduction in block length, the action probably was not of practical significance.

General Suitability of the Chemicals: With respect to fungus-inhibiting potency and freedom from harmful effects on wood, all the solu-

Table 3.--Weight losses caused by decay in test blocks treated for 1 month with tap water and with solutions in tap water of boric acid, chloro- and phenyl-phenols, and phenyl mercuric acetate, and subsequently leached for 1 month[1]

Treating material	Concentration	Solution pH	White oak			Mahogany		
			Weight loss produced by[2]			Weight loss produced by[2]		
			Poria monticola	Stereum frustulosum	Polyporus versicolor	Poria monticola	Stereum frustulosum	Polyporus versicolor
	Percent		Percent	Percent	Percent	Percent	Percent	Percent
Phenylmercuric acetate	[3]0.47		0	0	0	0	0	0
Sodium pentachlorophenate ("neutral"; 0.81 percent excess alkali)	5	8.1	0	+1	0	0	0	0
Sodium pentachlorophenate (technical; 3 to 4 percent excess alkali)	5	9.3	0	0	4	0	0	3
2, 4, 5 trichlorophenol (pure)	[3].08	6.9	0	0	+1	+2	2	0
Orthophenylphenol (pure)	[3].03		.7	.3	.7	2	2	2
Pentachlorophenol (technical)	[3].0047	7.5	0	.3	3	7	2	4
Boric acid plus sodium dichromate (20 to 1)	4.2	5.4	0	0	0	30	0	
Boric acid	4	5.5	4	0	0	25	0	+2
Tap water[4]		7.5	23	2	4	27	+.4	+.

Treating material	Concentration	Solution pH	Bald cypress			Atlantic white-cedar		
			Weight loss produced by[2]			Weight loss produced by[2]		
			Poria monticola	Fomes roseus	Lenzites trabea	Poria monticola	Fomes roseus	Fomes pinicola
	Percent		Percent	Percent	Percent	Percent	Percent	Percent
Phenylmercuric acetate	[3].47		0	0	0	0	0	0
Sodium pentachlorophenate ("neutral"; 0.81 percent excess alkali)	5	8.1	0	0	0	0	+2	0
Sodium pentachlorophenate (technical; 3 to 4 percent excess alkali)	5	9.3	+2	0	0	+4	0	+9
2, 4, 5 trichlorophenol (pure)	[3].08	6.9	3	2	0	+2	+4	
Orthophenylphenol (pure)	[3].03		0	1	.5	6	.8	
Pentachlorophenol (technical)	[3].0047	7.5	2	3	10	24	14	6
Boric acid plus sodium dichromate (20 to 1)	4.2	5.4	+2	0	0	24	9	0
Boric acid	4	5.5	14	9	7	33	18	11
Tap water[4]		7.5	21	18	3	39	31	27

[1] The test period was 2 months. Values for wood treated with tap water, pentachlorophenol, and orthophenylphenol are averages for three blocks. Other values represent a single test block in each case.

[2] Plus (+) values denote apparent increases in weight.

[3] The treating solutions were saturated with the chemicals at a temperature of about 75° F. Published information indicates the concentrations of the phenyl mercuric acetate and the trichlorophenol to be, in distilled water at 75°, about as listed here. Distilled water solutions of orthophenylphenol and of pentachlorophenol prepared in this Laboratory were indicated in analyses by the Dow Chemical Company to be as listed. Since the solutions for testing were made up in slightly alkaline tap water, the concentrations of the saturated phenolic solutions presumably were somewhat higher than the listed values. Technical pentachlorophenol has with it tetrachlorophenol, and because of the greater water solubility of the latter the solution of pentachlorophenol also probably contained more tetrachlorophenol than pentachlorophenol.

[4] Tap water was used in all respects like the chemical solutions as a treating material.

tions considered in this series of tests seemed reasonably suitable for use in bilgewater. However, other factors are involved. Phenyl mercuric acetate might be used in stored boats in which bilgewater is maintained to keep the seams tight or in which rainwater is allowed to accumulate, but it probably is too expensive for use in boats from which the bilgewater is pumped out frequently. Also, it might not be acceptable in some quarters because of the health hazard. Sodium pentachlorophenate is highly soluble in water, and would have to be replenished after each pumping of bilgewater. The same is true of boric acid; moreover, this chemical might corrode metal fasteners unless a way could be devised for maintaining an adequate amount of corrosion inhibitor such as sodium dichromate. The trichlorophenol probably would not be desirable for boats in service because of its pronounced odor, which is evident even in a saturated water solution of the chemical. All factors considered, orthophenylphenol and pentachlorophenol are deemed best for general bilgewater treatment.

Results of Further Tests of Orthophenylphenol and pentachlorophenol

Since orthophenylphenol and pentachlorophenol appeared promising on woods of substantial natural durability, a final series of tests was established on pine sapwood to ascertain the extent to which saturated water

Table 4.--Effect of Treatment of Test Blocks with Solutions in Tap Water of Boric Acid, Chlor and Phenyl Phenols, and Phenylmercuric Acetate on Their Length and Weight when Air Dry. (Blocks Treated 1 Month and Leached 1 Month)

Treating material	Concentration	Solution pH	Wood			
			White Oak	Mahogany	Baldcypress	Atlantic white cedar
			Relative length (original = 100) 1/			
Phenylmercuric acetate	0.47 2/	--	101	100	101	100
Sodium pentachlorophenate ("neutral"; 0.81 percent excess alkali)	5	8.1	99	99	100	101
Sodium pentachlorophenate (technical; 3 to 4 percent excess alkali)	5	9.3	98	99	99	101
2,4,5 trichlorophenol (pure)	.08 2/	6.9	100	100	99	101
Orthophenylphenol (pure)	.03 2/	--	99	100	100	100
Pentachlorophenol (technical)	.0047 2/	7.5	99	100	100	100
Boric acid + sodium dichromate (20 to 1)	4.2	5.4	99	99	100	99
Boric acid	4	5.5	99	100	99	100
			Relative weight (original = 100) 1/			
Phenylmercuric acetate	0.47 2/	--	97	99	97	104
Sodium pentachlorophenate ("neutral"; 0.81 percent excess alkali)	5	8.1	102	100	101	104
Sodium pentachlorophenate (technical; 3 to 4 percent excess alkali)	5	9.3	106	98	100	100
2,4,5 trichlorophenol (pure)	.08 2/	6.9	98	99	101	98
Orthophenylphenol (pure)	.03 2/	--	97	101	100	100
Pentachlorophenol (technical)	.0047 2/	7.5	97	100	99	99
Boric acid + sodium dichromate (20 to 1)	4.2	5.4	99	98	97	96
Boric acid	4	5.5	95	96	95	97

1/Values for wood treated with pentachlorophenol and orthophenylphenol are averages for 9 blocks. Values for wood treated with the other chemicals are averages for 3 blocks.

2/See footnote 3, table 3.

solutions of the chemicals might impart decay resistance to wood of low natural resistance. Also, in order to learn something about the fungus-inhibiting potency of the solutions themselves, the solutions were assayed by Petri-dish toxicity tests[5].

The pentachlorophenol used in these tests was pure rather than of technical grade, so that the results obtained could be referred strictly to the functioning of a single chemical. Moreover, the solutions were prepared in distilled rather than tap water, thus making the saturation concentrations of the chemicals a minimum amount or approximately so.

[5] See footnote 3, page 6.

Decay Resistance of Treated Sapwood Blocks: Weight losses caused by decay in the treated blocks are listed in Table 5. Blocks that were treated, only long enough to get them impregnated, decayed practically as much as or more than the untreated controls. In contrast, blocks that were soaked in the treating solutions for a month were variously improved in decay resistance. Both chemicals reduced decay by *L. lepideus* more than 80 percent; decay by the other two fungi was reduced approximately 40 and 50 percent by orthophenylphenol, and 20 and 30 percent by pentachlorophenol. The greater average effectiveness of the orthophenylphenol is attributable largely to the greater strength of its saturated solution.

Although the phenolic treatments

did not render the blocks immune to decay, the protection afforded by them surely would be an appreciable deterrent to decay in woods of low natural resistance repeatedly wetted by bilgewater. It is not clear why treatment for 1 month was effective whereas simple impregnation was not. Presumably with prolonged treatment the chemicals diffused into the wood and accumulated, at least up to a certain point, by differential adsorption. Even so, the amount of chemical transferred to the wood from the extremely dilute solutions must have been very small, the amount of pentachlorophenol, for example, perhaps not exceeding about .01 lbs. per cubic foot, a quantity considerably smaller than the amount needed to prevent decay by treatment with pentachlorophenol in oil solution[6].

The results with purified pentachlorophenol give a conservative picture of what might be expected from the technical grade of this chemical. The technical grade may contain as much as 12 percent of other chlorophenols, which are more soluble than pentachlorophenol in water and essentially as fungicidal.

Petri-Dish Toxicity Tests of Orthophenylphenol and Pentachlorophenol: The capacity of the orthophenylphenol and of the pentachlorophenol to inhibit the growth of fungi on malt-agar was shown by findings summarized in Table 6. As the concentrations of the solutions were not known precisely, they are given simply in terms of the saturation amounts (S) and various dilutions of them.

Of chief significance with respect to the potential protective value of treated bilgewater was the complete inhibition of growth of all the fungi by the saturated solutions, and in three fourths of the cases by dilutions of these solutions ranging from 1/5 to 1/2 the saturation value. Moreover, in 10 of the 12 test groups the fungi not only were prevented from growing but also were killed by the chemicals. Solutions of orthophenylphenol tended to be more potent than corresponding ones of pentachlorophenol, but the differences, in general, are not sufficient to be a factor of choice between the chemicals.

From this evidence it seems likely that the employed concentrations of orthophenylphenol and pentachlorophenol, while not suitable for wood preservation in ordinary circumstances, would, if present in bilgewater, protect wood wetted exclusively or frequently by the bilgewater.

In preliminary tests employing fresh water and artificial sea water, addition of these two chemicals caused no obvious increase in corrosion of wire nails or aluminum strips in the water.

Table 5.—Weight losses caused by decay in ponderosa pine sapwood blocks treated with saturated solutions in distilled water of orthophenylphenol and pentachlorophenol

Treatment	Weight loss produced by:1/		
	Poria monticola	Lenzites trabea	Lentinus lepideus
	Percent	Percent	Percent
Orthophenylphenol (pure; 0.03%)2/			
Blocks impregnated	32	31	27
Blocks impregnated, then soaked in the treating solution for 1 month	18	19	4
Pentachlorophenol (pure; 0.0016%)3/			
Blocks impregnated	40	40	25
Blocks impregnated, then soaked for 1 month in the treating solution	24	25	5
No treatment (controls)	36	31	30

1/Values are averages for 3 blocks.

2/Concentration ascertained by Dow Chemical Co. on a comparable solution prepared at this laboratory.

3/Approximate concentration; as listed in published data by the Dow Chemical Co.

Table 6.—Fungus Inhibiting and Killing Points of Water Solutions of Pentachlorophenol and Orthophenylphenol1/ (Saturation Concentration = S)

Test fungi	Pentachlorophenol		Orthophenylphenol	
	Inhibiting point	Killing point	Inhibiting point	Killing point
Miscellaneous molds2/	1/3 S	1/3 S	1/5 S	1/5 S
Polyporus versicolor	S	S +	S	S
Polyporus tulipiferus	1/2 S	S	1/2 S	1/2 S
Lenzites trabea	1/3 S	1/2 S	1/5 S	S
Poria monticola	1/3 S	1/3 S	1/3 S	S +
Ceratostomella pilifera	S	S	1/5 S	S

1/Ascertained by growth of the fungi on malt agar medium in which the water phase contained various dilutions of the respective pure chemicals. Dilutions were made from saturated solutions in distilled water at 75° F.; the tests were made at 80° F. Regarding the concentrations of the solutions, see footnotes 2 and 3, table 5.

2/Mold infection was obtained by exposing the test medium to the laboratory air for 1/2 hour.

In addition to the chemicals tested in the present study, several others were considered for possible use in bilgewater to control decay of wood wetted by the bilgewater. These were borax, boric acid, a mixture of borax and boric acid, phenyl mercuric acetate, and certain chlor and phenyl phenols. Except for the sodium salt of pentachlorophenol, all the phenolic compounds were tested in saturated water solution, and the concentrations in these cases were very small. Chemicals

(Continued on page 95)

Summary and Conclusions

A number of chemicals were tested in the laboratory as preservatives for

[6] Dunn, Catherine G. and Richards, C. Audrey. [illegible] Wood preservatives by soil-block tests [illegible] ect of the carrier on pentachlorophe[illegible]tions. 2. Comparison of a coal tar [illegible] a petroleum containing pentachloro[illegible]or copper naphthenate and mixtures of [illegible]m. Wood-Preserv. Assoc. Proceedings 46:131–145. 1950.

The Chemistry and Chemical Utilization of Beech[1]

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Beech is used extensively in the manufacture of well-known lumber products, but information about the chemistry and chemical uses of the wood is scant. This report was prepared at the U. S. Forest Products Laboratory to provide a source of information for those who are interested in the chemical composition and utilization of the species. Beech generally compares favorably to yellow birch and hard maple in chemical attributes.

Composition of Beech Wood

SUMMATIVE ANALYSIS: One way to study wood is by a summative chemical analysis. In this kind of analysis the four primary chemical elements of wood—extractives, ash, lignin, and holocellulose—are isolated and the weight of each is determined as a percentage of total weight.

Such an analysis was made of beech wood. In this analysis beech wood was compared with the wood of yellow birch and sugar maple, two hardwoods that are commonly associated with beech (table 1). The data show clearly that in chemical make-up beech is similar to birch and maple.

In this summative analysis the extractive component was broken down at the outset into two subcomponents: the materials soluble in hot water and the materials soluble in alcohol-benzene solution. This procedure shows up immediately any important differences in kind of extractives.

This analysis was carried forward to show the differences between sapwood and heartwood. The data (table 2) show that beech sapwood contains a greater proportion of extractives than heartwood, that the heartwood contains more ash and a little more lignin, and that sapwood and heartwood contain almost the same proportions of holocellulose.

Extractives form no part of the wood structure. In general, they can be removed from the wood by neutral solvents such as water, alcohol, ether, alcohol-benzene solution, and acetone. Extractives impart color, odor, taste, decay-resistance, and corrosive properties to wood. After they have been removed, an extractive-free wood residue remains.

This residue contains the structural elements—the fibers, wood rays, and vessels. It also contains most of the minerals that make up the ash, which is left after burning the lignin and holocellulose. Any one of the three structural components, if isolated carefully, will retain the microstructural pattern and shape it had in the original wood specimen (*16*).[3]

Proximate Analysis: Next, more intensive analyses of the four primary components of beech wood were made (*1*). In these analyses, wood samples were subjected to separate extractions with cold water, hot water, alcohol-benzene, and ether (table 3). Here too sapwood and heartwood were analyzed separately (table 4).

Extractives: Cold-water-soluble extractives include tannins, sugars, coloring matter, and salts. Hot-water-soluble extractives are similar; they also include starches. Thus the two water-soluble subdivisions of the extractives overlap. Both occur in greater concentrations in the sapwood than in the heartwood of beech.

Ether-soluble extractives include oils, fats, fatty acids, resins, resin acids, phytosterol, and waxes. The alcohol-benzene extractives are similar to those soluble in ether; they also include tannins. Alcohol-benzene extractives are present in larger amounts in the sapwood than in the heartwood of beech. Ether-soluble extractives are more concentrated in the heartwood.

Ash: Ash makes up 0.4 percent of whole beech wood by weight (table 5). Like most other wood ashes, beech ash is rich in potash. Other constituents of beech ash, expressed as oxides, are phosphorous, calcium, magnesium, iron, sulfur, silicon, and sodium.

Table 1.--Data from summative chemical analysis of wood (1)

(Based on weight of oven-dry wood.)

Species	Extractives soluble in--		Ash	Lignin	Holo-cellulose	Total
	Hot water	Alcohol-benzene				
	Percent	Percent	Percent	Percent	Percent	Percent
Beech	1.5	1.0	0.42	21.0	76.5	100.42
Birch	1.3	1.4	.40	19.3	77.0	99.40
Maple	1.1	1.2	.42	22.3	75.2	100.22

Table 2.--Comparison of sapwood and heartwood in summative chemical analysis (1)

(Based on weight of oven-dry wood.)

Species	Extractives soluble in--		Ash	Lignin	Holo-cellulose	Total
	Hot water	Alcohol-benzene[1]				
	Percent	Percent	Percent	Percent	Percent	Percent
Beech						
Sapwood	2.17	1.37	0.31	20.61	76.20	100.66
Heartwood	.43	.96	.57	22.26	76.85	101.07
Birch						
Sapwood	1.30	.97	.11	18.56	79.50	100.44
Heartwood	1.29	1.89	.50	20.19	76.45	100.32
Maple						
Sapwood	2.08	1.31	.32	20.33	76.26	100.30
Heartwood	1.20	1.22	.84	21.79	75.96	100.01

[1] Extractives soluble in water and alcohol-benzene determined on original wood.

[1] Sponsored by Northeast Technical Committee on Utilization of Beech; contributed to the Journal of the Forest Products Research Society.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[3] Numbers in parentheses refer to Literature Cited.

Table 3.--Data from proximate chemical analysis of wood (1)

(Based on weight of oven-dry wood.)

Species	Extractives soluble in--				Ash	Lignin	Holocellulose		Methoxyl	Acetyl	Pentosans	Crude and Klason cellulose
	Cold water[1]	Hot water	Alcohol-benzene	Ether			Alpha-cellulose	Hemi-cellulose				
	1	2	3	4	5	6	7	8	9	10	11	12
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Beech	1.2	1.5	1.0	0.60	0.42	21.0	50.0	26.5	6.3	5.0	25.0	60.5
Birch	1.0	1.3	1.4	.30	.40	19.3	49.7	27.3	5.9	7.4	26.8	58.7
Maple	.7	1.1	1.2	.45	.42	20.3	50.0	25.2	6.4	5.5	22.3	60.4

[1] Each of the subcomponents of extractives determined on the original wood.

The chemical elements found in beech ash indicate that it would be useful as a fertilizer—with the addition of an ingredient that contains available nitrogen. Potash promotes development of carbohydrates such as cellulose and starch in plant growth; it is necessary for growth of strong plant stems and good fruit and seed. It is especially useful for growing large potatoes. Phosphorus is also important in production of fruit and seeds.

Lignin: Beech has a lignin content of 21.0 percent. In this it is intermediate to birch and maple (table 3). The lignin content of beech heartwood is slightly greater than that of the sapwood (table 4).

Functionally lignin forms about 85 percent and hemicellulose 15 percent of a connective tissue (middle lamella) that binds the fibers and other structural elements of wood together (*15*). Lignin is also diffused throughout the cellulose in the fiber wall. It is at a high concentration in the middle lamella, gradually becoming less concentrated toward the fiber cavity.

Lignin adds stiffness to the structural elements. If it occurs in too-high concentrations the fibers become brittle, as in compression wood on the under side of leaning trees or large, drooping limbs. In contrast, tension wood, which occurs on the upper sides of leaning trees (*2*), has less lignin and more cellulose than normal wood.

Thin-walled springwood fibers that have been separated from one another by mechanical maceration remain inflated; but upon delignification they collapse to form ribbons. In their double-walled, ribbon-like condition the fibers are more flexible than in their normally inflated or tubular condition. This explains why chemically prepared pulp produces more flexible paper sheets than does mechanically prepared pulp such as groundwood or Asplund fiber.

Methoxyl, which is a minor chemical constituent, should also be mentioned. Beech wood is found to contain 6.3 percent of methoxyl (table 3, column 9). Roughly 85 percent of the methoxyl in wood is associated with the lignin; the remaining 15 percent is associated with the hemicelluloses and extractives.

Methoxyl is the nucleus of so-called "wood alcohol," technically known as methyl alcohol or methanol. Methoxyl has the chemical formula of CH_3O. If a hydrogen atom is combined with methoxyl, methyl alcohol (CH_3OH) is produced. Thus, by removing methoxyl from the lignin of wood and combining it with hydrogen, it is possible to make methyl alcohol. This takes place in destructive distillation. Beech, birch, and maple wood have all been used extensively in this process. This subject will be discussed further under destructive-distillation products.

Since beech has a normal lignin content for hardwoods, logging and sawmill wastes undoubtedly can be pulped at about the same cost for beech as for birch and maple. Data obtained from chemical analysis, however, provide no information on the physical quality of the fibers.

Holocellulose: Holocellulose is a white, fibrous, lignin-free solid material (*17*). It has two subcomponents—alpha-cellulose and the hemicelluloses.

Alpha-cellulose makes up about two-thirds of the holocellulose, or 50 percent of the wood (table 3). It is the major ingredient of paper. In purified form it is used extensively in the manufacture of explosives, synthetic textiles, and plastics.

The hemicelluloses make up one-third of the holocellulose, or 25 percent of the wood (table 3, column 8). They impart bonding properties to wood fibers in paper sheets and wet-formed board products prepared from crude wood fibers.

In yield of alpha-cellulose and hemicelluloses, beech compares favorably with birch and maple, which are acceptable for pulp. Since the total holocellulose yield of beech approximates that of birch and maple, the pulp yield of the three species should be comparable.

Table 4.--Analytical data on sapwood and heartwood (1)

(Based on weight of oven-dry wood.)

Analytical components	Beech		Birch		Maple	
	Sapwood	Heartwood	Sapwood	Heartwood	Sapwood	Heartwood
	Percent	Percent	Percent	Percent	Percent	Percent
Of wood:						
Ash	0.31	0.57	0.11	0.50	0.32	0.8
Extractives soluble in--						
Cold water	1.23	.23	1.20	.93	.81	.5
Hot water	2.17	.43	1.30	1.29	2.08	1.2
Alcohol-benzene	1.37	.96	.97	1.89	1.31	1.2
Ether	.20	.57	.36	.30	.10	.8
Acetyl	7.13	6.05	8.79	6.11	6.56	4.6
Methoxyl	6.25	6.44	6.01	6.04	6.34	6.4
Pentosans	25.55	24.49	26.89	26.87	22.78	22.6
Lignin	20.61	22.26	18.56	20.19	20.33	21.7
Cellulose	60.83	60.71	59.36	58.37	60.39	60.2
Holocellulose	76.20	76.85	79.50	76.45	76.26	75.9
Of holocellulose:						
Acetyl	5.15	4.76	6.13	5.81	5.12	4.0
Methoxyl	.95	1.24	1.31	.93	.83	.8
Pentosans	24.46	23.52	26.49	24.94	22.67	22.5

Table 5.--Chemical composition of ash from beech wood (19)

(Based on weight of oven-dry ash.)

Ash from--	Potassium oxide	Phosphorous pentoxide	Calcium oxide	Magnesium oxide	Iron oxide	Sulfur dioxide	Silicon dioxide	Sodium oxide
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Beech sapwood	41.0	4.6	26.7	14.4	3.5	4.1	1.3	1.1
Beech heartwood	38.7	1.5	33.3	12.8	2.1	3.9	2.1	.4

Table 6.--Chemical composition of bark (14)

(Based on weight of oven-dry bark)

Component of bark	Beech	[illegible]	Maple
	Percent	Percent	Percent
Extractives soluble in--			
Cold water	4.0	6.9	[illegible]
Ether	1.2	1.7	[illegible]
Ethanol-Alcohol	1.1	1.4	[illegible]
Total soluble materials	18.5	19.9	[illegible]
Ash	8.3	2.9	4.1
Lignin	37.0	40.[illegible]	39.7
Pentosans	13.7	16.6	14.4

Acetyls are minor chemical groups associated with the hemicellulose component of the holocellulose. By weight they comprise 5.0 percent of beech wood, as compared with 7.4 percent and 5.5 percent of birch and maple respectively (table 3). They are more concentrated in the sapwood than in the heartwood of all three species.

Composition of Bark

Analytical data on the composition of bark (*14*) from beech, birch, and maple are presented in table 6. Note that the hot-water solubility of beech bark is greater than that of the wood. So is ether solubility.

The ash content, 8.3 percent, is many times greater than that of the wood. Lignin content is also considerably greater. Except for the ash content, which is extremely high, the analytical data for beech bark approximate those for bark of birch and maple. No data are available for cellulose or holocellulose in the bark.

Composition of Beechnuts

According to a report by J. Russell Smith (*20*) beechnuts have been used as feed for swine in the New England States. In some sections woodlands are fenced with woven wire and when the beechnut crop is ready the hogs to be fattened are turned into the enclosure. Smith reports that in Europe the wild boar and semiwild hogs also feed on beechnuts. Beechnut oil has been substituted for butter in Europe.

Beechnuts contain the constituents of a good food (table 7). They have 22 percent protein, 50 percent fats, and 18 percent carbohydrates. One pound of beechnuts, according to Smith, contains as much protein as 6.6 pounds of milk. On burning, one pound of beechnuts furnishes 2,740 calories of heat. On this basis 3 ounces of beechnuts will replace 20 ounces of milk in heat value.

Chemical Utilization of Beech Wood

Wood Sugars: One possible way to utilize beech byproducts from logging and sawmill operations is to convert the waste materials into wood sugars by acid hydrolysis.

If holocellulose that has been isolated from the wood is treated with dilute sulfuric acid under controlled conditions, it can be converted almost quantitatively into a mixture of sugars and acetic acid. Some water enters into the chemical reaction and, as a result, the sugars obtained—plus the acetic acid—should theoretically weigh about 11 percent more than the holocellulose used. Under ideal conditions 100 pounds of cellulose material would produce about 110 pounds of sugar.

The sugars obtained from the alpha-cellulose portion of the holocellulose are mostly hexoses. Those obtained from the hemicellulose portion are mostly pentoses. The hexoses can be fermented to ethyl (grain) alcohol by yeast; the pentoses cannot.

When fine wood chips are hydrolyzed with acid, the holocellulose in them is partially protected by the lignin and extractives. As a result, some of the sugars are destroyed between the time the sugars form and the time they are removed from the acid medium. Furthermore, the acetic acid of the holocellulose is liberated. Thus the yield of sugars obtained from sawdust, even in the laboratory under controlled conditions, generally is considerably below the theoretical.

The yield was even less when the hydrolysis was tried on a pilot-plant scale in a large digester. (800 pounds capacity), using chips and hogged wood (*18*). Table 8 shows the yields

Table 7.--Chemical composition of nuts[1] (20)

Kind of nuts	Refuse	Edible portion					
		Moisture	Protein	Fats	Carbohydrates (Sugar and starch; crude fibers)	Ash	Fuel value per pound
	Percent	Percent	Percent	Percent	Percent	Percent	Calories
Beech	36.9	6.6	21.8	49.9	18.0	3.7	2,740
Butternut	86.4	4.5	27.9	61.2	3.4	3.0	3,370
Walnut	58.8	3.4	18.2	60.7	16.0	1.7	3,075

[1] Percentage yields are based on weight of oven-dry edible portions, except for refuse, for which percentage yields are based on weight of oven-dry shell plus edible portion.

obtained with both laboratory and pilot-plant methods (*4, 5*).

Molasses: In tests with this pilot-plant digester, wood sugars were found at about 4 percent concentration in the dilute acid-water solution drained from the digester. The acid was neutralized with calcium carbonate to convert the sulfuric acid to calcium sulfate, which was removed by filtration. From the neutralized sugar solution a molasses that has 50 percent sugars can be prepared by evaporating part of the water (*3*).

Beech wood yields about 50 percent sugars—1,000 pounds of sugar from 1 ton of wood. Accordingly it is possible to make 1 ton or 166 gallons (2,000 ÷ 12) of molasses having 50 percent sugar concentrations from 1 ton (dry weight) of beech wood (table 8). Molasses produced this way has been used in experimental feeding tests with chickens, hogs, and cattle. The results were promising.

Yeast: The yield of unfermentable sugars in a pilot plant at the U. S. Forest Products Laboratory was equal to 17 percent of the dry weight of the beech wood processed. These sugars, as well as the fermentable sugars, are suitable for growing yeast for stock feed. Yeast yields from the total sugar produced from maple wood in the pilot-plant were 25.2 percent of the sugars.

Although no beech sugars were used in the experiments for propagation of yeast, they appear to be suitable for yeast culture. Yeast is rich in proteins and vitamins and has been found suitable as a substitute for part of the protein requirements for stock feed.

Alcohol: Wood sugar produced from the alpha-cellulose portion of the holocellulose in wood is mostly all glucose. It is the same sugar that can be obtained from corn and cane and sugar beets. Yeast can convert this glucose into ethyl alcohol, the so-called "grain alcohol" that is present in beer and wine and is widely used in other commercial products (*6, 7, 11*). This should not be confused with the so-called "wood alcohol."

From the glucose of beech wood, ethyl alcohol can be produced that is equal in weight to 15 percent of the dry weight of the wood. On this basis, 1 ton of beech wood will produce 307 pounds—46 gallons—of ethyl alcohol.

Table 8.--Production of sugars, molasses, yeast, and alcohol from wood

(Based on weight of oven-dry, bark-free wood.)

Products	Beech	Birch	Maple
	Percent	Percent	Percent
On laboratory basis:			
Total sugars from sawdust	70.1	69.9	68.2
Fermentable sugars from sawdust	52.6	53.1	48.5
On pilot-plant basis:			
Total sugars from hogged wood	49.1	49.1	48.6
Fermentable sugars from hogged wood	32.1	32.3	32.0
Molasses from hogged wood	100.0	100.1	100.0
Yeast from hogged wood	--	--	25.2
Alcohol from hogged wood	15.35	15.45	15.3

Source: Data from Harris, Saeman, Leonard, and their associates. See Literature Cited.

Destructive-Distillation Products

If wood is heated in an oven from which air is excluded, the wood dries through the loss of free and adsorbed water. If the temperature is raised to 180° C. or higher, the wood begins to undergo destructive distillation, during which the so-called "water of constitution" is driven off. If the temperature is raised further, to about 270° C., the wood itself begins to decompose.

During this stage four groups of products are obtained: gases, pyroligneous acids, tars, and charcoal. These products are derived from the lignin and the holocellulose. Charcoal will not be discussed here; it will be the subject of another report in this series.

Gases: The gases include carbon dioxide, carbon monoxide, hydrogen, and methane. The first is an inert gas; the other three are combustible and can be used to produce heat. These gaseous products account for approximately 15 percent of the weight of the wood.

Pyroligneous Acid: The pyroligneous acid group—a solution of water-soluble products—comprises about 34 percent of beech wood (table 9). By weight, water is the major constituent of the group. Acetic acid is the principal useful constituent. It is derived principally from the acetyl groups of the hemicelluloses. Some acetic acid may also be derived from cellulose; this will be discussed later. Yields of acetic acid by destructive distillation of beech approximate 6 percent of the dry weight of the wood (table 10); similar yields are obtained from birch and maple.

Methyl alcohol is also present in the pyroligneous acid group. Yield from beech wood approximates 2 percent of the dry weight of the wood (table 10). This accounts for about 33 percent of the methoxyl in the wood; the

Table 9.--Yields of pyroligneous acid, tar, and charcoal from wood (8)

(Based on weight of oven-dry wood.)

Species	Pyroligneous acid free of tar and moisture			Tars			Charcoal		
	Heart	Slab	Mean	Heart	Slab	Mean	Heart	Slab	Mean
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Beech	32.3	35.4	33.8	9.7	10.6	10.1	43.1	39.4	41.2
Birch	34.2	34.3	34.3	9.6	8.5	9.0	39.0	38.1	38.5
Maple	33.4	34.6	34.0	12.5	12.3	12.4	40.2	37.6	38.9

other 67 percent has been shown to occur as derivatives in the form of methane among the gases and methyl and methoxy derivatives of phenol in the tar group of destructive-distillation products (*8*).

Tars: Tars constitute about 10 percent of beech wood (table 9). In these tars have been found traces of formic, propionic, and valeric acids and phenolics. This indicates that some of the constituents of the pyroligneous acid also occur in the tars in minute amounts. Besides these acids, some other basic materials have been identified among the tar constituents. They include ammonia, methylamine, dimethylamine, trimethylamine, and pyridine and its methyl derivatives.

Fractions of the tars have been shown to have toxic properties—similar to those of coal-tar creosote—toward wood-destroying micro-organisms. Beech wood, because of the pleasing flavor-producing properties of its creosote, is considered comparable to hickory for smoking meats. Creosote prepared from beech tar is also used extensively in medicinal products.

Klason (*9, 10*) distilled some woods, the cellulose from the same woods, and cotton cellulose. He found (table 11) that beech wood yielded approximately 35 percent of its weight in charcoal, as compared with 33 percent produced by its cellulose. Spruce and pine wood also produced more charcoal than their celluloses did; birch wood was an exception. Cotton cellulose, on the other hand, produced greater yields of charcoal than any of the woods did.

With the exception of birch, the woods also produced more tars than did their celluloses or the cotton cellulose. Acetic-acid yields were greater from the woods than from their celluloses; this indicates that some of the acetyl was removed from the celluloses during their isolation from the wood. Methyl-alcohol yields were higher from the wood than from the celluloses, which is explained by the fact that only a small portion of the total methoxyls of the wood is associated with the cellulose.

Table 10.--Methyl alcohol and acids obtained from heartwood and slabwood by destructive distillation (8)

(Based on weight of oven-dry wood.)

Species	Grown in	Methyl alcohol			Total acid as acetic		
		Heartwood	Slabwood	Mean heart and slab	Heartwood	Slabwood	Mean heart and slab
		Percent	Percent	Percent	Percent	Percent	Percent
Beech	Indiana	1.95	1.79	1.87	5.56	6.18	5.87
Birch	Pennsylvania	1.62	1.59	1.60	6.19	6.10	6.15
Maple	Pennsylvania	1.94	1.78	1.86	5.66	5.44	5.55

Chemically Modified Woods

Beech and other woods have been modified by combinations of chemical and physical treatments so as to improve their properties for special use requirements. Beech was converted to two products known as "Lignostone" and "Lignofol" in Germany before World War II (*13*).

Lignostone: Solid, dry beech wood was cut to the required sizes, evacuated of air in a chamber, and impregnated with a solution of partially prepolymerized synthetic resin (such as Bakelite) at 100° C. under 6 to 8 atmospheres pressure. The temperature was gradually increased to 130° C. for 5 hours.

This treatment increased the density and part of the strength properties of the wood and imparted some moisture resistance and dimensional stability. The wood product has been put to use as parts for textile machines, bearing plates, beaters, wood hammers, railing, skiis, and cog wheels.

Lignofol: Lignofol was prepared from beech veneer. The veneer plies were glued together with a synthetic adhesive, which was applied to the surfaces of the plies and allowed to diffuse into the plies before high temperatures and pressures (5,000 pounds per square inch) were applied for curing the glue. The plies were arranged either parallel or with some cross-bonding, depending on the use requirements for the finished product.

This material has been put to use in airplane parts, machine parts for the textile industry, and molds and forms for use in the shaping of metals.

Impreg, Compreg, Staypak: Similar modified wood products have been developed by American research laboratories (*21*). They include Impreg, which is similar to Lignostone; Compreg, which is similar to Lignofol; and Staypak, a heat-stabilized, compressed wood that has been heated during the pressing process under conditions such that the compression is not lost when the wood subsequently swells. Although Staypak swells, it will return to practically its original compressed thickness on drying.

Beech wood has not yet been used in making Impreg, Compreg, or Staypak, but it is believed to be suitable for making them. Such products made from beech should have properties similar to those made from comparable hardwoods.

Wax Treatment: A wax treatment for beech was also developed in Germany (*12*). Solid beech wood was impregnated with a solution of montan wax dissolved in trichlorethylene. This was done in a tank, from which air was evacuated. The wood was im-

Table 11.--Distillation products from wood, wood cellulose, and cotton (9, 10)

(Based on weight of oven-dry materials.)

Products	Beech		Birch		Spruce		Pine		Cotton cellulose
	Wood	Cellulose	Wood	Cellulose	Wood	Cellulose	Wood	Cellulose	
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Charcoal	34.97	32.91	31.80	33.39	37.81	34.86	37.83	36.93	38.82
Tar	8.11	5.23	7.93	9.58	8.08	6.28	11.79	4.85	4.18
Acetic acid	6.04	3.50	7.08	3.89	3.19	2.79	3.50	2.18	1.39
Methyl alcohol	2.07	.19	1.60	--	.88	.07	.96	trace	--
Methane	.47	.39	.54	.47	.62	.22	.59	.27	.27

pregnated with the warm solution at 130° C. and 8 atmospheres pressure until the desired amount of wax had been absorbed.

Excess pressure was then released and trichlorethylene vapor was generated by heating the tank. The vapor forced the excess solution into the supply tank, which was then shut off with a valve. The trichlorethylene vapor was distilled in a vacuum and passed into a condensing unit. The high vacuum and expansion of the residual air in the wood removed the trichlorethylene and water from the wood.

The author says that the treatment produces a wood product suitable for bobbins, beaters, cog wheels, frames for filter presses, tool handles, and shoe lasts.

Summary

Results of a proximate analysis in which the four major components of beech wood were broken down into their subcomponents show that the percentages of extractives, ash, lignin, holocellulose, alpha-cellulose, hemicelluloses, methoxyl, acetyl, pentosans, and Cross and Bevan cellulose of beech wood closely approximate the percentages of the corresponding components of yellow birch and hard maple.

These findings indicate that beech is on a par with birch and maple for the production of alpha-cellulose for cellulose derivatives; for the production of wood sugars, molasses, yeast, and ethyl alcohol; and for the production, by destructive distillation, of methyl alcohol, acetic acid, and charcoal.

Beech bark, like the bark of birch and maple, has more than one-third of its weight in lignin. Beech bark is especially high in ash content.

Beechnuts are valuable as a food for animals such as hogs. They contain ample amounts of protein, fats, and carbohydrates.

Literature Cited

(1) Freeman, R. D., and Peterson, F. C. 1941. Proximate analysis of the heartwood and sapwood of some American hardwoods. Indus. and Engin. Chem., Analyt. Ed. 13:803–805.

(2) (Gt. Brit.) Forest Products Research Board. 1950. Reports of the Forest Products Research Board 1939–1947. Gt. Brit. Dept. Sci. and Indus. Res. 94 pp. (London).

(3) Harris, E. E. 1947. Wood-sugar molasses from wood waste. South. Lumberman 175 (2201): 157–161.

(4) Harris, E. E., Beglinger, E., Hajny, G. J., and Sherrard, E. C. 1945. Sugars from wood. Hydrolysis of wood. Treatment with sulphuric acid in a stationary digester. Indus. and Engin. Chem., Indus. Ed. 37:12–23.

(5) —— and Beglinger, E. 1946. Madison wood sugar process. Indus. and Engin. Chem. Indus. Ed. 38:890–895.

(6) —— Hajny, G. J., Hannan, M. L., and Rogers, S. C. 1946. Fermentation of Douglas fir hydrolyzate by S. cerevisiae. Indus. and Engin. Chem., Indus. Ed. 38:896–904.

(7) —— Hannan, M. L., Marquardt, R. R., and Bubl, J. L. 1948. Fodder yeast from wood hydrolyzates and still residues. Indus. and Engin. Chem., Indus. Ed. 40:1216.

(8) Hawley, L. F. 1922. Effect of adding various chemicals to wood previous to distillation. Indus. and Engin. Chem. 14:43.

(9) Klason, P., Heidnstam, G., and Norlin, E. 1909. Investigation into the charring of wood. Ztschr. f. Angew. Chem. 22: 1205–1214.

(10) —— Heidnstam, G., and Norlin, E. 1910. Investigation into the charring of wood. Part 2. Dry distillation of the wood of the pine (Kiefer), fir (Fichte), birch, and beech. Ztschr. f. Angew. Chem. 23:1252–1257.

(11) Leonard, R. H., and Hajny, G. J. 1945. Fermentation of wood sugars to ethyl alcohol. Indus. and Engin. Chem. 37: 390–396.

(12) Nowak, A. 1939. Holzimprägnierung mit Wachstoffen und Kunstharzen. Mitt. des Fachausschusses f. Holzfragen 23:90–96.

(13) Reichers, Kurt. 1939. Uber Verwendung und Prüfung von hochverdichtetem Holz. Holz. als Roh- und Werkstoff. 2:(3) 109–116.

(14) Richter, George A. 1941. Cellulose from hardwoods. Indus. and Engin. Chem. 33:75–8.

(15) Ritter, George J. 1928. Composition and structure of the cell wall of wood. Indus. and Engin. Chem. 20:941.

(16) —— 1943. Structure of wood. Cellulose and cellulose derivatives. *In* Ott, Emil, High polymers, v. 5:286–292. Interscience Pubs. Inc. New York.

(17) —— and Kurth, E. F. 1933. Holocellulose, total carbohydrate fraction of extractive free maple wood. Its isolation and properties. Indus. and Engin. Chem. 25:1250–1253.

(18) Saeman, J. F., Buhl, J. L., and Harris, E. E. 1945. Quantitative saccharification of wood and cellulose. Indus. and Engin. Chem., Analyt. Ed. 17:35–37.

(19) Schorger, A. W. 1926. Chemistry of cellulose and wood. 596 pp. McGraw-Hill, New York.

(20) Smith, J. Russell. 1929. Tree crops. 333 pp. Harcourt, Brace & Co. New York.

(21) Stamm, A. J. 1946. Modified woods. Amer. Wood Preserv. Assoc. Proc. 42:150.

A FACTORY METHOD FOR TESTING HARDNESS OF GLUE JOINTS

Woodworkers have found that glues are usually moreabrasive than wood and that tools dull rather quickly in the machining of glued products. Some glues are harder thanothers, and, if the glue line of a joint made with a very hard glue is allowed to pass its entire length several times over the same spot in a planer or jointer knife, a nick is very likely to develop that is expensive to remove. In many cases, there-fore, it would pay a manufacturer to select a glue for his particular requirements that is the least abrasive of those havingthe qualities he desires.

The Forest Products Laboratory suggests the followingtest to determine the comparative hardness of joints made with different glues.

A number of pieces of wood (preferably softwoods) areglued together face to face, each individual joint being produced with one of the glues to be tested. Since the effect onthe knife depends, in part, on the thickness of the glue line as well as the type of glue, the gluing procedure should bethe same as that most commonly used in the plant. After the laminated block has been allowed to condition for a week ormore, one edge is cleaned of excess glue and squared up. The block is then run repeatedly over a jointer in such a way that each glue line passes over only one spot in the cutter. The depths of the respective nicks caused by the hardglue lines are then a rough measure of the abrasiv effect of the glues.

It is rather difficult, however, to detect differences in thenicks by a mere visual inspection. A better means of comparison is afforded if a smoothly planed softwood board isrun across the dull knives. The accompanying illustration shows a soft pine board that has been run across the jointerknives in the manner described. In this case the nicks were the result of jointing a laminated block in which 17 differentvarieties of commercial glues were used. The block was run over the jointer repeatedly until about 60 linear feet of eachglue line had passed over.—Tech. Note No. 223, U. S. Forest Products Lab.

Wood Research in the Philippine Republic

AT THE SPRING MEETING of the Northern California Section of the Forest Products Research Society a trans-Pacific telephone conversation was held between FPRS members in California and those in the Philippine Republic. The purpose of the conversation was to emphasize the fact that FPRS members throughout the world are working together to improve the uses of wood through research and that the Society serves as a vital means to disseminate new research information for the benefit of the industry in all parts of the world.

Excerpts from the conversation follow:

Good evening gentlemen. This is James C. Rowney speaking. Program Chairman for the Spring meeting of the Northern California Section of the Forest Products Research Society, which is being held in the California Room of the Palace Hotel in San Francisco, May 6, 1953. My able assistant is Mr. Harvey H. Smith of the U. S. Forest Experiment Station in Berkeley, California. The unique part of this meeting is that while we are meetng here in San Francisco at 8 P. M. this evening, May 6th, it is 11 A. M. May 7th tomorrow, Manila time. The people responsible for putting on this demonstration of radio telephone are the RCA Communications, Inc. under the personal direction of Vice President Mr. Harry E. Austin and our own national Vice President, Mr. Lester J. Carr who invited Mr. Florenzio Tomasas, Dean of Forestry, University of the Philippines to have a meeting simultaneously with ours in Manila. Mr. Tomasas, here is Mr. Carr.

Carr: Hello, Mr. Tomasas. How are you?

Tomasas: Fine, thanks.

Carr: That's good. I appreciated very much getting your letter. We have some 55 people here at this meeting. How many do you have at your meeting there?

Portable equipment used to transmit FPRS International Forum.

Tomasas: We have about 30 outside of the regular members of the Society. We have here important people interested in research and forest products. We also have here the representatives of M. S. A.—two of them who have been very, very helpful in trying to get the Forest Products Laboratory installed within a short time on this island. I think we had a little message from Mr. Good —if you don't mind.

Good: It is nice to hear your voice now at your meeting in San Francisco. We have been working on the Forest Products Laboratory over here and we have ordered the equipment. It will be coming in this fall. The building we hope to get going within the next six months and we hope in another year the institution will be a going concern.

Carr: That is very interesting to all of the people who are gathered here. We would like to have an answer to one question. Are you receiving all of your publications from the Forest Products Research Society?

Good: Yes, yes.

Carr: How does the present standard of these publications appeal to you fellows over there? Are they satisfactory?

Good: I'm going to let Mr. Tomasas speak for that.

Tomasas: Hello, Mr. Carr. The publications that you have been sending out have been very, very helpful. I wish that they could get out more to the people who are really interested and there are quite a number of people who are interested in joining the society and as soon as the Forest Products Laboratory is up I think we will have a very good bunch of people who are really interested in the research work.

Carr: Well, that's very good. I'm glad to hear that. We will send you a bunch of membership blanks from the Society. We are recording this conversation so that when we have our National Annual Meeting of the Society on June 15 we are going to play the record of this conversation for the interest of the entire society. They are all highly interested in the meeting that you are having and the fact that we can get together on the telephone hook-up and discuss what has been going on. In our meeting here today we have been going over the different phases of barking logs which was very interesting.

Tomasas: Yes, I'm sure it was.

Carr: We also had one paper presented on die-electric heating on hard board production. Does that sound interesting to you?

Tomasas: Oh yes, very much interesting.

Carr: We will have the secretary of this Northern California Section of the Society send you the preprints of these papers and we would like to receive some sort of communication from you on the papers you presented at your meeting today.

Tomasas: We will give you what we will be actually doing in the next few months along the line of research. We have already worked out certain work in connection with the National Research Council. You know we are very poor people and we hope to ask for donations here and there in order to carry on the work and with the help of the National Research Council we were able to do a little work, for example, on the control of the Russian (?) beetle as to whether they are getting in our logs before shipping abroad—that is some of the work we have more or less been completing.

Carr: That is very interesting. Now I have another gentleman here, Prof. Romero Fritz of the University of California.

Fritz: Tell them we want to send greetings from the University of California Forestry School.

Tomasas: Well, I am returning the greetings of the College of Forestry of the University of the Philippines and also this group of the Forest Products Research.

Fritz: You will be interested to know that the Forest Products Laboratory which is to be built at the University of California is to be a fact and they broke ground this last week.

Tomasas: We expect that our Forest Products Laboratory won't be behind what you are doing in the States.

Carr: Hello, Mr. Tomasas. This is Carr again. Before I break off on this end I want to tell you that we would appreciate your keeping in touch with us with the national office of the Forest Products Research Society at Madison.

Tomasas: I shall.

Industry Payoff in Lumber Seasoning[1]

J. M. McMILLEN

Technologist, Forest Products Laboratory,[2] Forest Service, U. S. Department of Agriculture

Describes how the fruits of research in lumber seasoning have been brought to the attention of industry through kiln-drying demonstrations throughout the nation. Examples of practical advantages of applying results of research are given. Author points out that despite tremendous accomplishments in seasoning that have taken place in the past seven years, the industry must strive for still more economical drying. He points the way to future advancements in the field of studying of stresses that develop in wood during drying and the ability of wood at different stages of drying to withstand these stresses.

SEVEN YEARS AGO this summer a small crew of U. S. Forest Products Laboratory staff members carried a message of better lumber seasoning to the wood-using industry. In the kiln-drying demonstrations that this crew put on, improved seasoning practices could be, and were, strongly recommended because they rested on solid research results that the Laboratory, other research institutions, and industry had obtained. To those of us who had a part in this undertaking, it has been gratifying to see the extent to which these practices have been put into use. Warping and associated waste have been tremendously reduced by means of sticker guides and automatic stackers, drying times have been shortened and quality of drying improved by new kiln schedules, case-hardening and its resultant planer splitting have been banished by equalizing and conditioning procedures, old kilns have been tuned up or replaced by modern forced-circulation, automatically controlled kilns, and many new kilns have been installed where no kilns existed before.

When I had a chance to visit the woodworking industry early this year, it was a pleasant surprise to see the vast contrast between the conditions today and those existing in 1946. It occurred to me that this is a good time to look back in review over the whole movement and to try to count up some of industry's solid accomplishments from application of the research results. It is perhaps easier for me to do this because I have not been so close to the job as those of the Laboratory's staff who had a more vital part in it.

Although this is largely the story of the U. S. Forest Products Laboratory's part in the country's improvement in lumber seasoning, and of the benefits, I fully realize that it was a partnership enterprise with industry. Credit also must go to the Forest Utilization Service, the arm of the Laboratory operating from most of the Forest Experiment Stations located throughout the country. The FUS men arranged cooperation with industry and kept up contact between the Laboratory and industry.

Extension of Research Findings to Industry

Before going into the industry payoff, let us first review what happened to bring it about.

Research Basis for Information: In the first place, there was a solid research basis for the information given out at the kiln-drying demonstrations. Even before 1910, Mr. Tiemann was gathering information on the physical properties of wood. After the establishment of the Laboratory that year, he and others continued to gather information on wood-moisture relations. Safe kiln schedules were set up in the twenties. Studies on southern hardwoods in the thirties brought out more practical kiln schedules. They also gave us basic information on what happens inside of wood, so far as internal stresses and strain are concerned, during the drying process.

During World War II, Laboratory men examined commercial dry kilns to certify them for the drying of wood for aircraft. These men were able, by intensive use of electric thermocouples and potentiometers, to accurately measure the temperature in various parts of the kilns. These measurements thoroughly confirmed facts about the operation of dry kilns that had been suspected but never proved before. They also pinpointed the causes of troubles that had long been bothering kiln operators. They wiped out the mysteries that had put kiln operation in a class with the intangible arts.

Demonstrations of Findings: When World War II ended, an opportunity developed for the Laboratory to present the results of kiln-drying research to the industry in a series of demonstrations. This activity was organized by the now retired W. K. Loughborough, well-known seasoning expert, under the general direction of Raymond C. Rietz, chief of the Laboratory's Division of Timber Physics. With all technical men in the division participating, a whole new series of publications was brought out. Two sessions were held in Madison. Then the crew went into the field, taking the information directly to industry. E. F. Rasmussen was in charge of these field sessions, and of the other Laboratory sessions that followed from time to time. Their success was largely due to his untiring efforts and to those of K. E. Kimball and F. K. Beyer. The rest of us who participated to a lesser extent can be proud to have been associated with them in this work. In the next 16 months 17 separate demonstrations were put on in North Carolina, Virginia, Maine, Arkansas, Illinois, Tennessee, Wisconsin, California, New Hampshire, Texas, and Washington. Nine more have been held since. About 700 dry-kiln operators, foremen, superintendents, and plant managers attended. In addition, about 150 have attended sessions conducted by other institutions with Laboratory aid. As stated before, it was possible for Rasmussen and the rest of us to strongly recommend the practices that we knew would pay off because of the solid research results back of them.

Ideas from Industry: Not all of the ideas in this crusade came from Laboratory research. Some came directly from industry's own investigations. Others occurred to the instructors when they bumped into the problems in the field at the same time they were teaching their cures. The first, and one of the most important ideas in the whole movement, was the

[1] Presented by E. F. Rasmussen at meeting of the Forest Products Research Society, Ohio Valley Section, April 23, 1953, at Louisville, Ky.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

fact, from direct cost keeping in one plant, that sticker guides, giving perfect sticker alinement, could result in a saving of 8 percent in overall lumber and handling costs. This fact greatly strengthened our arguments in favor of very careful piling and stickering. These arguments were at least partly responsible for equipment manufacturers increasing their development and sale of automatic stacking equipment.

A problem that the kiln-demonstration crew bumped into during plant visits was the very great deterioration of stock that was not given adequate protection during green storage and air drying. These observations strongly backed up our recommendations for adequate pile roofs or completely covered green-storage yards. Another problem was planer splitting in lumber that had not been conditioned to relieve set or casehardening at the end of the kiln-drying process. This observation backed up our strong recommendations for complete equalization and conditioning of lumber before it is removed from the kiln.

More ideas have come from substantial research projects carried out by industry during the past 7 years. The Redwood Seasoning Committee, of the California Redwood Association, made up of kiln operators and plant managers concerned with seasoning problems, built and operated an experimental dry kiln and conducted exhaustive tests. Other individual firms and industry groups have done other research jobs and made the results known.

Better Dry Kilns: The past 7 years have just about completed the transition from natural-circulation to forced-circulation kilns. The heightened interest in good seasoning stimulated the sale of modern kilns. The information on kiln performance spread through the kiln-drying demonstrations stimulated kiln manufacturers to bring their kilns up to high quality; so that there are several different makes of kilns on the market that fully meet the highest standards. There also has been a big growth of kilns economically heated by oil or natural gas. Although these kilns do not have humidity control required for green hardwoods, they are drying great quantities of softwood lumber not adequately dried before, also some well air-dried hardwoods for products not requiring relief of casehardening. These kilns have been set up not only in the gas and oil fields of the South, but in the California area as well.

In addition to the kilns newly installed, existing kilns have been tuned up to utilize their fullest capabilities.

New Kiln Schedules: The pioneer research on stresses developed in wood as it drys and the practical work done on kiln schedules for a few specific woods such as blackgum enabled the kiln-demonstration crew to preach a new concept for kiln schedules for hardwoods. In 1946 about all they could do was preach, however, for there was no comprehensive publication of new kiln schedules. They urged kiln operators to go forth and apply the principles on their own grounds. When you consider how much the lumber in a single commercial charge is worth, you cannot help but realize that the progress made by the kiln operators themselves was slow. This approach obviously was not satisfying the demands of the industry. In 1950, O. W. Torgeson took this matter in hand. He systematically combined the results of research in various Laboratory studies. He then went out into the industry and checked on the most advanced schedules it was using. From these, he put together the revolutionary kiln-drying schedules published in Forest Products Laboratory Report No. D1791. These new standard methods give an acceleration to drying of considerable magnitude. Also, with kilns under better control at that date and kiln operators better trained, it was thought practical to recommend, for some woods, milder initial conditions than had ever been recommended before. This lowered drying degrade and did not hinder drying acceleration because of the new methods of lowering relative humidity soon after the start of the run. Correct use of the other accelerator, high temperature, after all of the free water is gone, was also included in the new schedules. The new schedule for 4/4 red oak made it possible to reduce the drying time, for stock at 70 percent moisture content, from 31 to 21 days. Oak that has been partially dried to about 40 percent moisture content can be finished in 11 days. These times include equalizing and conditioning periods of about 24 hours each.

Moisture Quality Control: Finally, as a means for checking up on the performance of kiln-drying equipment and procedures, Rietz adapted the tool of moisture-quality control. Some industrial use is already being made of this tool, but there is room for considerably more. It not only aids in spotting troubles before they get into the final stages of manufacture, but allows use of reasonable industrial standards for uniformity.

Industry Application and Benefits

Now let us look at how the industry is applying the new kiln-drying information and what benefits it is receiving. An article has recently appeared in the magazine "Wood and Wood Products" on how one manufacturer has improved his kiln-drying and handling setup and made considerable savings. This same type of improvement has gone on all over the country. It is hard, of course, for anyone to put his finger on actual savings that have been realized by industry during the past 7 years because of the approximate doubling of labor and other costs. In preparation for this paper, however, letters were sent to 15 firms scattered over the country. These firms had kilns in operation at the start of the period, sent representatives to the kiln-drying demonstrations, and kept up contact with the Laboratory. These firms probably were about average in drying equipment and skill in 1946. Now we consider them a little above average in the amount of improvement in seasoning practices. As expected, these firms could supply little concrete information, but we believe that the qualitative statements they were able to make are a valid representation of the type of gain that any woodworking firm can make that will devote greater attention to its seasoning. To help visualize the application these statements may have to your own problem, I have grouped them by regions. It is, of course, impossible to give credit to all companies to whom credit is due within any of these regions or to cover fully every wood-producing or wood-using area.

Southeast: In the Southeast, the demonstrations were sponsored by an industry group, the Southern Furniture Manufacturers Association. Because of this sponsorship there was a big participation by industry representatives. As a result, there have been broad applications and widespread benefits. The company recently reported in "Wood and Wood Products" was one that did not send representatives to our demonstrations, but it had contact with the same information through contacts with the Forest Utilization Service at Asheville, N. C., and a kiln manufacturer's representative who did. This company replaced 14 natural-draft kilns with 5 modern cross-circulation kilns. It added 2 more modern kilns to dry lumber from small mills. This company reported a nice saving in steam over the old kilns. It also reported that other practical advantages showed up in the planing mill, where considerably less checked, crooked, and cracked lumber were found. The company now is able to plane the lumber within 24 hours of the time it comes from the kiln, instead of waiting 30 days as in the

past. Two million board feet of pine, cypress, and oak lumber are run through the kilns per 4-week period.

Another company reported it has changed methods, kilns, sticking, and added automatic stackers. It cannot say just how much has been gained over the past or any particular year, but company officials know that they made savings in piling and in other phases. With new boilers, they have lowered steam costs and overall costs. In other words, the cost of lumber from the time it comes in to the point of cutting has been reduced.

Another company reported its drying improvements, proper stickering, and kiln schedules saved a great deal by reducing waste in the manufacture of flooring. Overall conversion waste has been reduced 4.7 percent since 1948. From 3B Common and Better oak, the yield of flooring and related products remains 70 percent Select and Clear grades, with less than 1 percent of No. 2. A 4.7 percent saving on 15 million board feet of lumber per year, with an assumed cost of $60 per Mbm, adds up to $42,000 per year. It was estimated that about one-third of these benefits were attributable to improvements in seasoning practices, or at least $1 per Mbm. Additional benefits from good seasoning, such as savings in time and worry, could not be measured in dollars and cents. Other factors in the overall reduction of conversion waste were the placement of the men trained in kiln operation in different departments and giving them further on-the-job training in grading, stacking, and milling.

South: In the South, kiln-drying demonstrations were held at Memphis, Tenn., Fort Smith, Ark., and Lufkin, Tex., under sponsorship of industrial organizations and the Texas Forest Service. In Texas the demonstrations not only fostered the regular improvements in kiln operation, but they also brought the kiln operators in contact with information on use of hygroscopic chemical-seasoning agents to reduce checking in thick oak and other hardwoods.

One company reported that it had not been keeping cost figures on kiln drying, but that company officials believe they are getting very low costs and good results. This company reported that all of its thicker lumber is helped by a chemical-seasoning agent if applied when the lumber is strictly green. By use of this treatment, the time that the lumber has to be held on the yard has been reduced, and the final lumber is better. Degrade has been reduced 22 percent. Honeycombing has been reduced to about 4 percent in contrast to the 10 percent previously experienced.

California: All over California drying facilities have been improved. In the Los Angeles and San Francisco areas many new kilns have been installed.

One operater in the Los Angeles area has reported that he had no concrete figures to back him up, but he sincerely believed that he had reduced his drying time considerably and at the same time improved the quality of the seasoning.

The improvement made in the redwood industry, a result of its own research, deserves a little more lengthy discussion. The California Redwood Association reported that there has been a marked improvement in kiln drying, but because of different accounting systems and lack of complete records for costs in years prior to the experiments, it has not been able to put an accurate dollars-and-cents value on the savings. The association's seasoning director, however, has estimated that savings may be in excess of $10 per Mbm. Recent efforts have been directed toward improved air drying. Many mills have thus been able to reduce the total cost of drying heavy segregation 4/4 stock by $7 per Mbm.

Northwest: The great Northwest area, because of its high output, has long recognized the importance of economical seasoning. It had, prior to the series of dry-kiln demonstrations, highly organized kiln operators' clubs meeting fairly regularly. One of the earlier field demonstrations was held in that area, however, and some of the western operators have come to the Madison sessions. As a result, that area has made some advancement during the past 7 years. The magnitude of advancement was smaller, however, because of the already high level of operation there.

One company reported difficulties in determining the increase in the quality of the drying, but it is sure that, by the careful checking of the drying process and the development of improved schedules, there has been an improvement. This company has statistics, however, on the cost of stacking mechanically in comparison with hand stacking. In 1949 six men hand-stacked for four kilns at a cost per Mbm of $1.15. In 1953 with mechanical stacking the six men handled 10 kilns, and direct costs per Mbm were reduced to $0.17. In 1949 hand unstacking costs per Mbm were $1.57; in 1953 direct unstacking costs per Mbm by mechanical methods were $0.95.

Another company reported that there were too many factors involved in its annual cost figures to show savings. During this period, however, it was able to change drying standards so that it now dries to a considerably lower moisture content than in the past. By better knowledge of the fundamentals of drying wood, this company was able to use higher temperatures safely during the final stages of drying to accomplish this end. The drying is being accomplished in the same time and with the same direct labor costs. The company also finds a much more uniform product with a definite saving being made because the operating departments turn back far less lumber because of high moisture content. In addition, this company is using a moisture-checking system which insures that the lumber on the output end is properly and uniformly dried.

Northeast and North: In the Northeast, the first missionary work was done by Roy Carter, then a member of the Forest Utilization Service of the Northeastern Forest Experiment Station. Some of the earliest field demonstrations were held in Maine and New Hampshire, however. At the start of the period there were comparatively few modern dry kilns in that area. Since that time there have been many dry kilns installed, and a well-trained group of kiln operators has sprung up.

One of the companies in the area reported there is little it can say on dollar savings because labor has gone up more or less in proportion to that in other parts of the country. This company does feel, however, that it is doing a better job of kiln drying than in the past. This is attributed to the installation of two new kilns and to the careful stacking of their lumber, particularly to keeping the edges of the kiln loads square.

In the North, where old kilns of the natural-draft variety had been installed early in the wood-utilization game, the changeover to modern kilns was at first slow. This area now has moved along with the rest of the country. The use of sticker guides and other means of properly piling and protecting the stock before it goes into the kiln are now the rule rather than the exception.

One company reported that it had no figures or records from which it could develop comparative costs, but that it undertook kiln-drying improvement from one standpoint only—quality. When the company started its program, it was having so much rejection, warping, poor glue joints, etc., that something had to be done. As a result, the troubles have been about 95 percent cleared up and the

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Review of Hardwood Developments in the Pacific Northwest

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Growth of hardboard industry in the Pacific Northwest is trace. Summary is given of various processes and capacities. Formation of Hardboard Division, Pacific Northwest Section of FPRS, is reviewed.

Industrial Development

DURING THE PAST SIX YEARS the Pacific Northwest, including Oregon, Washington and British Columbia, has witnessed the development of an important regional hardboard industry. The stature of this local industry may be gauged by the facts that:

1. In number of plants and production capacity the hardboard industry of the Pacific Northwest rivals that of Sweden although that country's industry began almost twenty years earlier.
2. The region's hardboard production capacity is between 20 and 25 per cent of the total United States capacity and may reach 30 per cent in 1954.
3. United States hardboard production is roughly half of Douglas-fir plywood production when compared with plywood on the basis of surface measure (1/8 inch hardboard vs 3/8 inch plywood).

Another important point about the Pacific Northwest hardboard industry is that the entire output is made from sawmill or veneer mill residues. It can almost be said that each hardboard plant is supplied entirely by wood residues from one sawmill or veneer mill. Thus, additional products and additional jobs have been created with no additional drain on the region's forest resource.

The local hardboard industry, which began with the establishment of the Chapman Manufacturing Company's plant at Corvallis, Oregon in 1946, parallels Sweden's industry in many respects. The latter's hardboard industry which began in 1929 with the erection of the Swedish Masonite plant, developed according to the traditional European pattern of numerous small plants (1). By 1957 Sweden had 12 plants manufacturing hardboard, 9 o which made insulating board also; but the combined hardboard production of the 12 plants was approximately 400 million square feet of 1/8-inch board or little more than one-half the capacity of Masonite's one American plant. The eight plants now producing hardboard in the Pacific Northwest have an estimated annual capacity of about 340 million square feet. Both Sweden and the Pacific Northwest have successful plants producing as little as 10,000 tons of board per year.

The fact that Sweden granted no basic product patent to Masonite was an important factor in the early development of the Swedish industry. No plants were constructed in the Pacific Northwest until Masonite's basic United States' product patent ran out.

A final point of similarity is that the Asplund Defibrator process was important in establishing the industry in both areas. The majority of Swedish plants still use this process while the first four plants constructed in the Pacific Northwest employ Asplund Defibrators.

In reviewing the early development of the local hardboard industry it is interesting to trace the pioneering work of Ralph Chapman. In 1944, Chapman was plagued by the general shortage of metals for the construction of home freezer cabinets. At that time he asked the Oregon Forest Products Laboratory to investigate the experimental production of a wood fiber-resin mixture for moulded cabinet parts. Oil and resin shortages plus cost considerations delayed a solution to the problem and in 1945 Chapman asked the Laboratory to shift the emphasis to a cooperative investigation of hardboard panels that would take simple curves. At the same time he made definite plans for plant construction and in the spring of 1946 a plant began production of odd-sized panels for freezer cabinets. In 1947, Chapman made major changes in his processing equipment and began to market 4-by 8-foot sheets of hardboard. The freezer company which led to Chapman's interest in hardboard was sold and later dissolved while Chapman continued to pioneer in the hardboard industry by licensing his process and supervising construction of plants in British Columbia and Minnesota.

It is difficult to assess Ralph Chapman's full contribution in establishing a hardboard industry in the Pacific Northwest. Certainly he must be credited with first demonstrating that small sized plants, having investment costs of less than a half million dollars (as of 1947), could succeed in America.

Chapman not only built the first plant at Corvallis, Oregon, but supervised construction of an identical plant for Canadian Forest Products Limited at New Westminister, British Columbia. This second plant began board production in 1948.

The third plant in the Pacific Northwest, which was established in 1949 by the Stimson Lumber Company at Forest Grove, Oregon, followed very closely the process used in Sweden, forming the wet mat continuously on a Fourdrinier wire rather than in a 4-by 8-foot deckle box as did Chapman.

Further variations in processing came rapidly after 1950. Anderson and Runckel, working for the Oregon Lumber Company, demonstrated that Douglas-fir bark could be used in hardboard (2); a plant based on their process began operation in November, 1951.

The 'semi-dry' process, developed by the Plywood Research Foundation, was adapted to commercial production by the Anacortes Veneer Company at Anacortes, Washington in 1952, and by the Coos Bay Lumber Company at Coos Bay, Oregon in 1953.

The Long–Bell Lumber Company at Longview, Washington developed its own 'dry' process for a board to be used in its factory department, and began production on a large pilot plant scale in 1952.

The eighth northwest plant, that of Cascades Plywood Corporation, likewise developed its own 'dry' process and began production this year. This is the first plant to state that it uses planer shavings rather than chips for hardboard.

Table 1.—SUMMARY OF PACIFIC NORTHWEST HARDBOARD PLANTS, PROCESSES AND CAPACITIES*

Firm Name	Plant Location	Type of process†	Annual production capacity (a) (in million square feet)	Tons of dry wood required per day (b) 250 days/year
Operating Companies				
Chapman Mfg. Co.	Corvallis, Ore.	Wet—batch	24	38
Pacific Veneer Div.	New Westminister,			
Canadian Forest Products Ltd.	B. C.	Wet—batch	24 (¼")	63
Forest Fiber Products Company	Forest Grove Oregon	Wet—continuous	62	98
Oregon Lumber Co.	Dee, Oregon	Wet—continuous (with bark)	56	88
Anacortes Veneer Co.	Anacortes, Wash.	Semi-dry	30	45
Coos Bay Lumber Co.	Coos Bay, Ore.	Semi-dry	70	105
Cascades Plywood Co.	Lebanon, Ore.	Dry	36	54
Long-Bell Lumber Co.	Longview, Wash.	Dry	15 (¼")	37
1953 Capacity			317	528
Under Construction				
Oregon Fiber Products Inc.	Pilot Rock, Oregon	Wet—dry	80	126
Weyerhauser Timber Company	Klamath Falls, Ore.	Dry	90	134
1954 Capacity			487	788
Projected Plants				
Rogue Hardboard, Inc.	Grants Pass, Ore.		---	---
Washington Hardboard Products, Inc.	South Bend, Wash.		---	---
Willamette Fibre Board, Inc.	Sweet Home, Ore.		---	---

*Plant capacities are taken from a Table appearing in the 1953 Review Number of the Lumberman, Vol. 80, No. 4, page 132, March 1953.

†The broad process classification used here is based on the moisture content of the fiber mat at the time of pressing. Wet—over 100% n.c.; semi-dry—10–100% n.c.; dry—less than 10% n.c.

(a) Square footage is based on ⅛-inch board unless otherwise stated.

(b) Conversion factors used are:
⅛-inch board— 725 pounds per M square feet
¼-inch board—1200 pounds per M square feet
Wet process—92% yield of dry weight of wood
Dry or semi-dry process—97% yield of dry weight of wood

Two plants now under construction in eastern Oregon, one at Klamath Falls by Weyerhaeuser Timber Company, and one at Pilot Rock by the Pilot Rock Lumber Company, will introduce further process variations. Weyerhaeuser will use its own 'dry' process while Pilot Rock will use a process similar to that employed by U. S. Gypsum Company at Greenville, Mississippi.

The present and projected hardboard plants of the Pacific Northwest are listed, together with their reported or estimated capacities, in Table 1.

Formation of a Hardboard Division in the Pacific Northwest Section of FPRS

The rapid expansion of the hardboard industry in the Pacific Northwest, which captured the interest of the regional FPRS membership, has led to the formation of a hardboard division in the local section. The following is a review of the events from which this hardboard division and its well-defined objectives evolved.

In November, 1951, the Pacific Northwest section featured a panel discussion of hardboard; a program which stimulated a group of members to meet informally the next day. This group agreed that a major problem of the expanding industry was the development of standard methods of evaluating hardboard properties. It was soon obvious that the magnitude of the job required the combined efforts of many individuals and organizations. The group endorsed the work on hardboard testing that was underway or planned, and expressed the hope that the work of all agencies could be coordinated. Finally the group agreed to hold an open meeting immediately prior to the next FPRS section meeting.

In February 1952, some forty individuals, representing hardboard manufacturers, sellers, a major user, resin suppliers, and public laboratories, met in Seattle to discuss hardboard testing, including such points as:

1. Are currently used test methods satisfactory?
2. What additional properties of hardboard require standard methods for evaluation?
3. What progress is being made to check the adequacy of presently used test methods and to develop additional test methods?
4. What agencies write standard test procedures and how can newly developed information be made available to these agencies?
5. How can research on hardboard testing best be encouraged and coordinated?

One hardboard producer reported the recommendations of a newly formed industry technical committee. He stated that although the manufacturers hoped to form a hardboard association soon they desired help in obtaining more data on hardboard testing.

A review of past research on the evaluation of hardboard properties emphasized the need for increased work and maximum coordination of efforts. Finally the group appointed a representative 10-man coordinating committee to:

1. Encourage and coordinate investigations of hardboard test procedures.
2. Explore the best methods of cooperating with organizations that draft or approve test procedures.
3. Plan the next open meeting to be held immediately prior to the spring section meeting of FPRS.

The group decided that the question of formally affiliating with an established organization such as FPRS be postponed until the group's objectives were more clearly established.

At its next open meeting at Portland, Oregon, in May, 1952, it was decided that the Pacific Northwest section of FPRS was the organization best fitted to sponsor the group's efforts. Consequently, the coordinating committee drafted a resolution requesting the formation of a hardboard division within the section, and outlining the objectives of such a division. The resolution was presented at the section's business meeting on May 20 and passed after considerable discussion.

The resolution read in part "The objective of this division will be to stimulate the development of uniform test procedures for hardboard. This will be accomplished by: (1) collecting test information already available; (2) encouraging research pertinent to hardboard testing; and (3) making the information obtained available to those organizations responsible for setting hardboard standards."

The newly created hardboard division has held half-day meetings on the day preceding each of the last three section meetings. At its meeting in October, 1952, the division voted to form a permanent coordinating committee and outlined methods of selecting committee members. Briefly, each of the six laboratories or universities represented were to designate a representative for an indefinite term; hardboard manufacturers were to elect four representatives (one to represent each of the three principal manufacturing processes and one to represent sales) for one year terms; and resin manufacturers supplying hardboard resins were to elect one member to represent their industry. The section chairman and a representative of the national subject matter committee on composition board would sit with the committee as ex-officio members. The representative nature of the coordinating committee is important for at present it is the functioning body of the hardboard division. As such it has the responsibility for achieving the division's objectives.

In February, 1953, the permanent coordinating committee membership was announced and the committee's responsibilities were clarified. The chairman and secretary of the committee were designated as chairman and

secretary respectively of the hardboard division. It was again emphasized that the objectives of the hardboard division were limited specifically to "stimulating the development of *uniform test procedures* for hardboard" and it was agreed that activities of the division should be limited to these objectives. A recent report by Lewis (3) has stressed the need for more complete test procedures.

Early meetings had reviewed information on test procedures, including past work, new test methods required, and results of current research, but it was not until the February meeting that time-consuming organizational problems were settled. The division is now free to devote its complete attention to the responsibility of coordinating research on hardboard test procedures. The meeting of the hardboard division in April 1953 illustrated the future pattern of activity. In this case the committee presented to the division a panel discussion of recent and related research on the evaluation of hardboard properties. This discussion emphasized current work at public laboratories; the next will emphasize the investigative work of some manufacturers. Interest in the hardboard division is proven by the fact that attendance at division meetings is almost as large as that at section meetings.

The growth of a hardboard industry and a parallel development of a hardboard division of FPRS in the Pacific Northwest have been reviewed. Space does not permit consideration of the important question of future developments. An observer much better qualified to predict future hardboard markets has given an encouraging analysis (4), but much depends upon the acumen of the many hardboard manufacturers in the Pacific Northwest. Their records of successful operation in other fields and their realistic view of the competitive situation indicates a continuing, although slower, expansion in hardboard production.

References Cited

1. Lowgren, Uno "Wallboard Manufacture in Sweden According to the Defibrator System." *Pulp & Paper Industry,* Vol. 21, No. 1, January 1947.
2. Anderson, A. B. and Runckel, W. J. "1950 Utilization of Douglas-fir Bark in Hardboard." *FPRS Proceedings,* Vol. 4, 301–308.
3. Lewis, Wayne C. "The Hardboard Industry of the United States", *Journal of FPRS,* Vol. II, No. 4, November 1952.
4. Devlin, Charles E. "Hardboard Developments in the Pacific Northwest." *Lumberman,* Vol. 79, No. 3, March 1952.

FINISH CHECKING

(Continued from page 14)

els faced with rotary-cut yellow birch, plain-sliced black walnut, and plain-sliced white oak.

Panels (10 x 30 in.) were assembled with loose- and tight-cut veneers having both the open and closed faces exposed. These panels were reduced to a test specimen size of 10 x 5 in., given either a heavy or light sanding, filled or left unfilled, and finished with either a synthetic varnish or a high grade lacquer.

After being subjected to conditions of alternating high and low humidity to simulate as nearly as possible actual seasonal variations of moisture content, specimens were examined on both the finished and cross-sectional surfaces. The relative severity of checks in the finish was determined by an examination of the finished surface. The cross-sectional surfaces showed clearly that the great majority of finish checks were directly traceable to knife checks in the face veneers.

The conclusion was reached that with certain combinations of veneer quality, assembly method, and depth of sanding, finish checks due to knife checks may be either minimized or completely eliminated.

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VENEER DRYING

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This weighing apparatus was vertically adjustable. After drying, the specimens were left in an oven at 220° F. for about 24 hours in order that the "ovendry" weight might be determined as a basis for calculating moisture contents from the various weight measurements taken during the drying cycles.

Temperature measurements were made by two methods. On specimens 1/8- and 1/4-inch thick, temperatures inside the specimens were measured with thermocouples inserted in a 0.020-inch hole from the edge to the center of the specimen, and cemented there with a heat-resistant rubber-base cement. Surface-temperature measurements were made on specimens of all thicknesses with the aid of calibrated temperature-indicating waxes. Visible powder or dust spots were made on specimen surfaces, each spot of a wax of known melting temperature. As the wax reached its known melting temperature, it fused and the spot took on the appearance of a grease spot. From comparative tests made with thermocouples, it appeared that the wax method was consistent and accurate in this particular application.

The design of the drying rate tests followed the factorial method and the results were analyzed statistically (2). The significance of the conclusions discussed in this paper was well established by recognized statistical test methods.

In addition to the data on drying rates, considerable information was also uncovered on shrinkage and the development of drying defects. This will be presented in a subsequent paper.

References Cited

1. Bethel, James and Robert J. Hader. 1952. Hardwood veneer drying. Journal of Forest Products Research Society II (5): 205–215.
2. Cochran, Wm. G. and G. M. Cox. 1950. Experimental designs. Wiley, New York.
3. Higgins, James J. 1952. The air drying of paper. Tappi 35 (3): 93-99.
4. Keylwerth, Rudolf. 1952. Der Verlauf der Holztemperatur waehrend der Furnier- und Schnittholztrocknung. Holz als Roh u. Werkstoff. 10:87-91.
5. Ogura, Takeo. 1951. Studies of the mechanisms of drying wood. 4. On the effects of surrounding conditions on moisture conductivity. Forest Exp. Sta. (Japan) Bul. No. 51:77–83. Meguro, Tokyo, Japan.
6. Sherwood, T. K. 1929. The drying of solids, II. Indus. and Engin. Chem. 21:976-980.
7. Stamm, A. J. 1946. Passage of liquids, vapors, and dissolved materials through softwood. U. S. Dept. Agr. Tech. Bul. No. 929. Washington.
8. Walker, Wm. H., W. K. Lewis, Wm. H. McAdams, and E. R. Gilliland. 1927. Principles of chemical engineering. Chapter XIX. Third edit. McGraw–Hill, New York.

STORAGE

(Continued from page 35)

2. Forest Products Laboratory. 1943. Coatings for the prevention of end checks in logs and lumber. For. Prod. Lab., For. Service, U. S. Dept. Agric., Rept. No. R1435, 13 p., illus.
3. ——. 1944. Effect of moisture changes on the shrinking, swelling, specific gravity, air or void space, weight and similar properties of wood. For. Prod. Lab., For. Serv., U. S. Dept. Agric., Rept. No. R1448, 29 p., illus.
4. ——. 1951. Control of moisture content and shrinkage of wood (in process of revision 1953). For. Prod. Lab., For. Serv., U. S. Dept. Agric., Rept. No. R1903–7, 15 p., illus.
5. Lindgren, R. M. 1930. Prevention of deterioration in stored logs by chemical treatment. Lumber Trade Jour., pp. 37–38, Nov. 1.
6. Scheffer, T. C., and T. W. Jones. 1953. Control of decay in bolts and logs of northern hardwoods during storage. Northeastern For. Expt. Sta., For. Serv., U. S. Dept. Agri., Station Paper, in press.

COLLECTION TECHNIQUES

(Continued from page 40)

given weight of material. It is also necessary to calculate weights in order to be assured that the transporting vehicle has sufficient capacity to hold the minimum weight requirement for economical transportation. Coarse material can be considered comparable to pulpwood, and it will vary in solid cubic content according to the size and number of pieces contained in a cord of 128 cubic feet, or any other cubic-foot standard. The variation for slabs obtained from sawmills is from about 60 to 84 cubic feet of solid material per cord. The general average is between 70 and 80 cubic feet, and the most commonly used averages by industry are 72 to 77 cubic feet.

Chips are like slab wood or rough wood to the extent that the smaller the size, the greater the expansion and the more space they will require. By using pulpwood chips as a base, then variations can be estimated both for larger and smaller material. Pulpwood chips that occupy a space of 100 cubic feet will contain from 20 to 47 and average about 33½ cubic feet of solid material. Sawdust, being much finer than pulp chips or slabs, is more uniform, has fewer voids, and will contain about 45.4 cubic feet of solid wood for each 100 cubic feet of space occupied.

Using the average volume and the green weight of wood, the weight per 100 cubic feet can be calculated. Using pulp chips as an example, this weight will vary from about 900 to 2,200 pounds, depending upon the species. Similar calculations can be made for other types of material and for individual species.

Truck Transportation

Generally, truck transportation is economical for distances up to about 60 miles. The distance will vary with size of truck, road conditions, and loading methods. An important cost factor is loading and unloading time. This is one of the major reasons for bundling coarse residue. At small mills, residue collects slowly, and so removable truck bodies or trailers are placed so that slabs can be piled on them. This permits a single truck or truck-tractor to haul for several mills. The same system is used at larger mills producing chips. One truck-tractor is used for two or more trailers. If it is necessary to use trucks, then the fastest way of filling them is from overhead storage bins with large chutes or openings. The capacity of truck and trailer units varies with the maximum size and weight restrictions of the various states. A common trailer size for chips and hogged fuel, particularly in the West, is one that holds about 2,000 cubic feet.

A variety of unloading methods is used, but the most rapid is to dump the load. Dump trucks and tilting platforms are both being used. Cranes are also used to lift the front end of semi-trailers. Conveyor chains or belts along the bottom of the vehicle body are used where the receiving plant is not equipped to receive dumped loads.

Railroad Transportation

There is considerable variation in railroad transportation. Some pulp companies receive chips in open-top cars, and others insist that chips be shipped in closed boxcars. Coarse residue, on the other hand, is generally shipped in open-top cars or on flat-cars with stakes.

Loading open-top cars with chips is relatively easy by terminating the conveyor system above the car. A series of storage bins or a chain conveyor along the track above the cars can be used. One such system has vertical outlets adjusted so that when the chips pile up to the opening the flow stops automatically. On a chain conveyor system, the chips fall through the first opening until the flow stops and then carry on to the second and successive openings.

It is necessary to throw chips to the top end of closed cars in order to load them. Two common methods are used to do this: One is to use a flexible outlet on pneumatic conveyor systems, and the other is a swivel loader. This latter device is a short, fast traveling belt upon which chips are dropped from a conveyor or chute. Slope and speed of the belt are such that chips are propelled from the doorway to the upper end of the car.

Some open-top cars have hopper bottoms that greatly facilitate unloading. The most common method of unloading other cars is with pneumatic conveyor systems.

Storage

Handling wood residue almost always involves storage. At the collection point, space or facilities must be provided to hold material either to accumulate a vehicle load or while vehicles are being placed for loading. Storage facilities are particularly important at the processing plant to avoid shutdowns due to lack of material.

Summary

Collection of wood residue involves segregation by size class and concentration at a central loading point, transportation to the delivery point, and handling at the production plant. Several types of conveyor systems are available for handling wood residue. Selection of equipment for a particular application depends upon the class and volume of material, room available, and methods of handling. In all cases storage facilities should be available to smooth out irregularities in the flow of material.

References

Anon. Chips, The Great New Bonanza of the Forest Industries. The Lumberman, V. 78, No. 11, p. 56–59, Nov. 1951.

Bell, G. E. The Handling and Transportation of Sawmill Waste for Pulpwood. Forest Products Laboratories of Canada, Ottawa.

Guthrie, J. and Richmond, R. H. Silo Type Chip Storage. Pulp and Paper Magazine of Canada, V. 49, No. 12, p. 89–90, Nov. 1948.

Harter, A. T. An Improved System for Chip Storage and Handling. Pulp and Paper, V. 23, No. 13, p. 64–69, Dec. 1949.

McBride, C. F. and Rymer, K. W. Utilization of Sawmill Waste for Pulpwood. Forest Products Laboratories of Canada, Vancouver, B. C.

SELLING LUMBER

(Continued from page 43)

we spent about $12,000 at Forest Products Laboratory to prove or disprove what was already known. We think neither we nor our customers should take any unnecessary chances.

Our services to those who buy from us include learning how our production will fit into their special requirements; in other words, finding customers who need what we have. We do not "dump" anything on the market. We search until we find customers who can use profitably each item we produce.

As an example, we have two customers who vie for our entire accumulation of S4S shorts—1 x 3/12 inches x 2/5 feet long. One is a large retail organization; the other is a millwork concern.

We save these shorts for them because they have a continuous special need for them.

One of our wholesalers uses all the 1 x 1-inch and 1 x 2-inch Fir Edgings we develop. (Although our production is primarily Redwood, we bring in what Douglas Fir is in our tracts.) This wholesaler knows he can depend on getting practically all of these items we produce.

We could go on reciting similar cases.

As a further service we usually phone these folks the minute our inventory shows stock we know they want. Even airmail might be too slow for our customer's needs.

Our industrial customers are regularly under the watchful eyes of our wholesalers and ourselves to make sure they are getting continuous satisfaction from the lumber we sell them. We do not wait for trouble to develop; we try to prevent its occurrence.

Naturally, our year in and year out customers are very dear to us, but every card, letter or inquiry gets prompt and full response whether it be from the DuPont Company or from John Smith of Podunk; whether it be for carloads of lumber, for information on finishing siding already on a house (and maybe bought from a competitor) or for guidance on any lumber subject. When a customer wants to know something, we get the answer for him. We do not send him to somebody else.

Speaking of research, The Pacific Lumber Company maintains its own equipment at the Institute of Paper Chemistry, Appleton, Wisconsin, and has spent literally hundreds of thousands of dollars on research in the last fifteen years—research intended to help sales.

And it has helped sales!

Here's a statement that may amaze you.

For years we have been oversold on our sawdust, shavings, knots, edgings, trimmer ends and bark.

The sawdust and shavings go into Prestologs which we ship by the carload for home heating and cooking.

Some of our edgings, etc., are blown up under a Masonite license to produce a product we call Palco Seal which is used to seal porous oil wells in Texas, Oklahoma, and other states. —More of this so-called waste lumber is chipped for shipment to roofing paper manufacturers.

Most of the bark is processed into Palco Wool, an insulation material widely used in cold storage construction and, to a lesser extent, in homes. Some of the remaining bark is further refined into what we call Fibre "A" which has more than one use. Part of it is utilized as a special type of insulation and part is shipped to one of the large storage battery manufacturers who further processes it into battery separators. A portion of the remainder ends up as Palco Pete—used as an aerator in gardens and on lawns.

Now a lightweight insulation roofing board is being made of a mixture of bark and wood paste. A liquid by-product of this process is being utilized for chemical purposes.

All of the above brief outline merely details some of the efforts of the personnel on the payroll of The Pacific Lumber Company. We do not want you to get the idea that we think there is genius in any form . . concealed or otherwise . . connected with these efforts. It is just plain hard work, day in and day out. It is part of a planned sales program at which we work, good times and bad. These labors lay the groundwork for those in the field who do the real selling.

These "firing line" men include salaried representatives, wholesalers and commission men in states, cities, and towns throughout the nation. Some sell exclusively for Palco while to others our line is just one of several. Practically to a man, though, they prize their Pacific Lumber Company connection and through their constant devotion we have been sold "right up to the hilt" for years on all sizes and descriptions of stock from $\frac{3}{16}$ inches thick by 2¾ inches wide by 9 inches long up through all thicknesses, widths and lengths.

ECONOMIC ASPECTS

(Continued from page 50)

ization—Keystone of Intensive Forest Management.

8. F.P.R.S. Preprint No. 129 (1950), Louis T. Stevenson, Economic Aspects of Papermaking Fibrous Raw Materials.
9. F.P.R.S. Preprint No. 108 (1950), George L. Drake, Utilization of Low-Grade Hardwoods and Softwoods in the Pacific Northwest.
10. Forest Policy for New Hampshire (Report of Governor's Forest Pol. Comm.), Dec. 1952.
11. Donald J. Hardenbrook, "Forest Magic", Address before the Cleveland Society of Security Analysts, February 5, 1952.
12. Monthly Review, Federal Reserve Bank of Boston, August, 1951.
13. Canada Department of Resources and Development, Forestry Branch Bulletin No. 103, 1952—J. H. Jenkins, Wood Waste Utilization in Canada.
14. Northeastern Wood Utilization Council, Bulletin No. 30, November, 1949.
15. John Kenneth Galbraith, American Capitalism: The Concept of Countervailing Power, Houghton Mifflin Co., Boston, 1952—especially Chapter VIII.
16. The Forestry Chronicle, Vol. 28, No. 4 (December 1952), A. W. Bentley, Trends in North American Forestry, p. 21.
17. F.P.R.S. Preprint No. 128 (1950), Frank J. Hanrahan, Lumber Research to Meet Modern Competition.
18. New York Times Magazine, April 26, 1953, Sumner Slichter, 'We Can Have Peace and Prosperity'.
19. Duke University School of Forestry Lectures, Number 8, 1949, George A. Garratt, Forest Utilization in the Transitional Stage.
20. F.P.R.S. Preprint No. 159 (1951), P. M. Schaffrath, The Manufacture and Utilization of High Quality Chemigroundwood Pulps.

WOOD CHIPS

(Continued from page 51)

$1,000.00 per car. These costs are paid by Longview Fibre Company.

Our investment in these cars amounts to a total of more than one-quarter-million dollars. It is of course essential that a chip supplier be dependable for a number of years so that we will have an opportunity to amortize this large investment in transportation facilities. Carloads of chips arriving at our mill in Longview are unloaded by placing the cars over an

open pit which is equipped with a conveyor at the bottom for moving the chips into the mill. It requires approximately 45 minutes to unload a car containing 20 units measuring 200 cubic feet per unit.

The cost of maintaining the railroad cars is divided between the railroad and ourselves. For example, on the gondola car it is our obligation to maintain that equipment owned by us, namely the extended wooden sides and the rake used for assisting the unloading. In the case of the converted boxcar we must maintain the 18 unloading doors and their catches, the three rakes, bulkheads and slope sheets. Repairs other than the above are paid for by the carrier.

The average turn-around from all sources is approximately 10 days, therefore each car is capable of delivering three carloads, or approximately 60 units of chips per month.

In addition to the rail chip cars we also operate, as a private carrier, a fleet of 11 tractors and 30 ten-unit trailers. This equipment is used to transport chips within 30 to 60 miles of Longview from origins where rail facilities are not available, or transit time would be excessive. The trailers are unloaded by backing the equipment up a ramp, disconnecting the trailer from the tractor and lifting the trailer by an overhead crane to about a 50 degree angle. The chips are dumped into a hopper equipped with a conveyor at the bottom to transport the chips into the mill.

The following figures on chip volumes, are for compacted units loaded in a rail car.

Chips produced from residues of sawmills and veneer plants vary considerably, depending upon the type of mill and the grade of log used. A typical sawmill, without barking, will produce from .14 to .21 units of chips per thousand feet of lumber cut. The average veneer plant will produce approximately 5.5 units per day per million square feet per month, 3/8-inch plywood basis. A veneer plant manufacturing plywood at the rate of four million square feet per month (3/8-inch basis) will produce from suitable residues approximately 484 units.

Our standard of chip quality will allow only a small amount of bark and rot—less than 1%. We cannot accept any chips containing char. To assist our suppliers with their problems involving chip quality, chipper operation and car loading, we have an engineer that visits each supplier at regular intervals.

A sample of chips is taken from every rail car and truck in order to ascertain the quality. If any of these samples show below-standard quality, the supplier is contacted immediately by telephone and is advised of the difficulty. Our field engineer is also alerted and if the situation does not improve, he then visits the supplier and assists him in meeting our quality specifications.

Future expansion of chip production is dependent upon the market to utilize the increased volume. Whole log barking will in most instances double the volume of chips at a sawmill, and the recent introduction of the Nicholson Mechanical Barker will make it possible for many small to medium size mills to install this type of equipment.

MECHANICAL BARKING

(Continued from page 55)

trogen-fixing, decay producing bacteria, the bark will decompose in a matter of two or three weeks. Of course, sawdust can be treated in the same manner but it takes longer to break it down and it will not break down of itself in a pile or in the ground without absorbing considerable nitrogen from whatever source it may be able to obtain it.

As to what extractives and acids give bark a low pH rating, tests made by Twining show the following results on a moisture free basis:

This appears to show that the acidity comes from the tannin. The laboratory found a high percentage of non-tannins readily soluble in water, using the standard tannin test. It did not check these non-tannins carefully but believes they show possibility of use in plastics.

Steam distillation of the bark shows that it is practically free from pinene, santene, terpene and other volatile oils, esters, etc. This again is in contrast with the heartwood of the trees from which the bark was removed.

Powdered bark was also extracted with various solvents with the results shown in the following table.

Table 3.—EXTRACTIVES OF BARK OBTAINED BY TREATING WATER FREE MATERIAL WITH VARIOUS SOLVENTS

Solvent	White Fir	Sugar Pine	Ponderosa Pine
Petroleum ether extract	1.09%	1.06%	1.26%
Ethyl ether extract	7.69%	2.10%	2.40%
Methyl alcohol (Methanol)	16.04%	18.18%	6.98%
Isopropyl alcohol (Isoproponal) extract	12.86%	14.55%	5.00%
Benzol extract	1.46%	1.04%	1.19%
Carbon Tetrachloride extract	1.33%	1.05%	1.34%
Water extract	18.70%	24.38%	11.33%

The largest extracts, obtained by Methanol and Isoproponal, were the only ones in amounts high enough to be of commercial value, if practical use can be found and market established. This has not been attempted as yet but we hope to do it or get someone to do it for us in the not too far distant future.

As is usually the case, one investigation of this kind always leads to the need for many more. We hesitate to suggest the undertaking of them to this group of men whose thought and attention is already directed in so many directions, all valuable and important to the wood using industries. All available evidence shows us that barking of logs can be profitable from several manufacturing standpoints, but it is our belief and opinion that the major benefits will only be achieved when research has pointed the way for bark to play a major role in agriculture and industry.

HYDRAULIC BARKING

(Continued from page 58)

The following intermediate sizes, sometimes called the "unit" type, having 42" turning wheels, have been furnished for:

11. Columbia River Paper Mills, Vancouver, Washington.
12. Oregon Pulp & Paper Co., Salem, Oregon
*13. Weyerhaeuser Timber Co. Mill "C", Everett, Washington

The "package" type Barker with 36" turning wheels for up to 10' logs has been furnished for:

14. Rayonier, Incorporated, Hoquiam, Washington
15. Publisher's Paper, Inc., Oregon City, Oregon

For the sawmills barking up to 42' or 44' logs, 72" to 80" in diameter, we have furnished or are furnishing the following:

16. Weyerhaeuser Timber Co., Mill "B", Everett, Washington
17. Weyerhaeuser Timber Company, North Bend, Oregon
**18. Weyerhaeuser Timber Company, Enumclaw, Washington
*19. Union Lumber Company, Fort Bragg, California

* Signifies machines which are to be shipped during the first half of 1953.
** To be in operation during May, 1953.

AERATION

(Continued from page 71)

change of gases, including oxygen and carbon dioxide and the production of water vapour. In decay studies, where fungi are held in closed containers under laboratory observation, it is essential that adequate venting should be provided, if the organism is to continue normal growth. If provision is not made for the exchange of gases, and a metabolic equilibrium maintained in this respect, many cultures

will be suffocated, wholly or partially. Conversely, persistence of fungal growth within a closed culture jar for long periods is sufficient evidence that, although the jar is closed, an imperfect seal exists which allows some gaseous exchange.

Rate of Decay

The results of the work herein reported indicate that the rate of decay in wood blocks, measured by the loss in weight over a specified period, in thoroughly sealed but vented soil jars, is more constant than in jars capped by other means, and is also sufficiently rapid. Furthermore, the soil moisture content was higher and more constant within the vented jars than in jars aerated by other means. While a quite high moisture content is to be desired for the substratum in decay studies, the fact that this condition was more nearly constant in the vented jars is of greater significance.

As the vent of the type described ensures a positive and uniform means of aeration, the gaseous exchange accompanying the decay processes is standardized for all soil jars covered in this manner, and no variation in the behaviour of cultures contained in the jars can be attributed to erratic ventilation.

A measured degree of ventilation can produce an approach to uniformity in the effect of fungal attack on wood blocks within a series of soil jars as regards destruction of the wood material, and it can also maintain a high moisture content in the soil which is practically uniform over a series of jars. There is lack of uniformity in the moisture contents of the blocks at the end of the exposure period. In this series of tests there was variation in the final moisture contents of the decayed blocks, even within the same jar. These moisture contents are related to the metabolism of the fungi concerned, to the amount of mycelium allowed to remain upon or contained within the test blocks, and to the humidity of the air supply provided through the vents.

BILGEWATER

(Continued from page 78)

of slight water solubility would, if the solutions were sufficiently fungistatic, be most practical to use since they could be maintained in the bilge for long periods without replenishment despite frequent pumping out of the bilgewater.

The solutions of all the chemicals increased substantially the decay resistance of blocks that had been soaked in the solutions for a period of 1 month. Solutions containing borax, however, chemically damaged blocks of white oak and mahogany and therefore would not be safe in bilgewater in contact with wood of hardwood species. The more promising chemicals had little or no adverse effect on the constituents of wood responsible for its natural decay resistance; consequently, their presence in bilgewater would not make the associated wood more decay susceptible if treatment of the bilgewater were discontinued.

Although not superior in all respects, orthophenylphenol and pentachlorophenol appear to possess most fully the following desired qualities of a bilgewater chemical: low solubility in water, capacity of the saturated water solutions to completely inhibit fungus development, safety in handling with ordinary precautions, harmlessness to wood, non-corrosiveness to metal fastenings, freedom from objectionable odor, and low cost. Blocks of susceptible pine sapwood treated for 1 month with saturated water solutions of these chemicals had about 20 to 80 percent less decay than comparable untreated blocks. In Petri-dish tests the solutions prevented growth of all fungi used and in most cases killed them. Judging from these results, bilgewater saturated with orthophenylphenol or with pentachlorophenol might be expected to preserve any wood that is wetted by it frequently or exclusively.

INDUSTRY PAYOFF

(Continued from page 88)

company is entirely satisfied with results.

Ohio Valley: Many men from industries in the Ohio Valley have attended the demonstrations at the Laboratory, although no demonstrations have been held in the area. It is from this area that we have received a significant report on the benefits of new Forest Products Laboratory kiln schedules.

One kiln operator used the new schedule for 500,000 board feet of 8/4 maple. The schedule worked very well. He found less surface checking, less end checking, and not nearly so much warping. He got much more even, or uniform, drying than before. In the drying of 4/4 to 6/4 poplar he used our new schedule as a starting point down to 20 percent moisture content. Then, on the basis of his knowledge of drying fundamentals, he shifted to a 200 ° F. temperature and a 40 ° wet-bulb depression. He reported that at the end of the run he had a softer board with little, if any, case-hardening. He still employed the equalizing treatment, which he considered very important to finish all the lumber to the same moisture content.

Present Status and the Future

This brings us to the question as to what the kiln-drying operators and the industry are doing at the present time and what provision is being made for future advances.

Interchange of Information on Hand: The men who have participated in the kiln-drying demonstrations, and others vitally interested in advancing seasoning practice, have set up among themselves 13 separate kiln-drying clubs or associations. These associations meet regularly throughout the year to hear basic papers or to interchange experiences. The meetings are very well attended. Just a few days ago the New England and the Keystone kiln-drying associations met together at Chicopee, Mass., with 160 men in attendance. In the middle of May all the western clubs, the Southern California, the Central California, the Northern California-Southern Oregon, the West Coast, the Washington-Idaho-Montana, and the Eastern Oregon-Southern Idaho groups will hold their annual joint meeting at Boise, Idaho, with an attendance of as many or more in prospect.

The kiln-drying demonstrations are now being put on by forestry schools and state institutions in various parts of the country, with the Forest Products Laboratory assisting. Additional 2-week sessions will be held at the Laboratory if demand develops.

The Forest Products Research Society has been active in promoting seasoning advancement. Numerous fundamental and applied research papers have been presented at the annual meetings. These meetings will continue to be a good forum for this type of paper. Many seasoning papers have been presented at the FPRS section meetings.

In addition, the Forest Products Research Society has set up a Wood Drying Committee. This committee is interested in coordinating the research that is being done in the field of lumber seasoning and in helping to publish in news-digest form some of the talks presented at the dry-kiln association meetings. The committee also will be of assistance in getting some of these talks printed in the FPRS Journal.

The Forest Products Laboratory is now bringing together and condensing the most vital of its information on kiln drying into a new kiln operator's manual. The contacts that the

Laboratory personnel has had with the industry will be very helpful in making this new publication a useful tool for the industry as a whole.

New Research: Although the seasoning accomplishment of the past 7 years, built on at least 50 years of research, have been tremendous, no industry can rest on its laurels. There is no question but what labor and other costs will continue to rise. To stay in business, the wood-using industry must keep the prices of its products within the reach of the purchasers.

Research is being done at the Forest Products Laboratory for the advancement of kiln schedules from their present stage, which we consider high standards, to optimum schedules. Studies are being made of the stresses that develop in the wood during drying and the ability of the wood at different stages of drying to withstand these stresses. If this research can be carried out in the near future, the industry can expect a whole new series of optimum kiln schedules in 5 to 10 years. By this time well-trained kiln operators and properly functioning kiln equipment will be the rule throughout the industry rather than the above-average situations. The Laboratory is ready now, however, to work with individual operators.

Economical kiln-operating conditions are also scheduled for early research. Some of the kiln companies and certain kiln operators have been recommending and using part-time operation. They believe this reduces costs, although they realize that drying times are lengthened. The Laboratory is completing equipment by which it can carefully check various combinations of the full-time or part-time heating, humidity control, and air circulation. This research will be designed to determine the exact economies of the various methods so that individual companies can apply the information to their own situations.

Furthermore, it must be realized by research personnel and industry operators alike that all the answers cannot possibly come from one laboratory. It is therefore expected that many of the problems will be solved by state colleges, other research institutions, and industrial laboratories. It is also hoped that the graduate schools of the universities will enter more strongly into fundamental research in the drying of wood, to help advance the technology on a broader front. Then there has to be a continuous testing and probing of the research results by the producing and manufacturing industries or the results will not fit the needs.

Abstracts

The preparation of abstracts from world literature in many languages is so highly specialized and costly that the Forest Products Research Society has no abstracting service of its own. For the abstracts in this issue of the JOURNAL the Society is indebted to the respective abstract journals indicated, from which they have been selected with the kind permission of the editors. Readers wishing information in addition to that given in these abstracts should consult the original articles referred to. Copies or additional information can not be supplied by FPRS or the abstract journal. The journals from which abstracts are published in this issue are as follows:

BULLETIN OF THE INSTITUTE OF PAPER CHEMISTRY, published monthly at Appleton, Wisconsin by the Institute of Paper Chemistry, subscription price $25 per year. This Bulletin publishes over 3,600 abstracts per year on subjects of interest to manufacturers of pulp, paper, fiber board and allied products.

CHEMICAL ABSTRACTS, published semimonthly by the American Chemical Society, Executive Office—1155 Sixteenth Street, NW, Washington 6, D. C., subscription price $60 per year plus postage. This abstract journal publishes many thousands of abstracts annually with broad coverage of world literature in the entire field of chemistry and allied subjects.

FOREST PRODUCTS AND UTILIZATION ABSTRACTS are published quarterly by the Commonwealth Agricultural Bureaux of London, England, as a separate reprint of decimal sections 3, 7, and 8 of Forestry Abstracts, for the facility of those interested chiefly in the field of wood utilization. The abstracts are prepared by the Commonwealth Forestry Bureau, Oxford, England, and the utilization section contains about 1,200 titles and abstracts per year from literature in some 30 languages and covers all aspects of forest utilization from cutting and extraction through marketing, mechanical, and chemical processing to minor forest products. FPRS members interested in obtaining the complete issues of Forest Products and Utilization Abstracts should communicate with the Secretary of the Society.

TECHNICAL BULLETIN OF THE FURNITURE DEVELOPMENT COUNCIL is published bimonthly by the Council at 11 Adelphi Terrace, London W. C. 2, England. The Technical Bulletin publishes hundreds of abstracts and reviews from world literature annually, relating to the various phases of the furniture manufacturing industry. Subscription price is $5 per year.

Timber Harvesting and Lumber Manufacturing

Bocko, N. A., and Perfilov, M. A. Rabota na lesozagotovkah v nocnoe vremja. [Night work on felling sites.] *Lesn. Prom.* 11 (10), 1951 (4–10). [Russ.]

An illustrated description of lighting installations on felling sites, enabling skidding and loading at the forest depot to be done at night. In accordance with a Soviet standard (GOST 3825–47), the illumination near winches and electric (transformer) stations should be 1 lux, that required for the coupling, uncoupling, and loading of tree-length and other logs should be 0·5 lux, while in other places (auxiliary equipment) an illumination of 0·2 lux is sufficient. Theoretical considerations and practical experience both show that best results are obtained with floodlights; the floodlight projector used in the U.S.S.R. has a power of 1000 watts (220 volts), and weighs 23 kg. Three projectors of this type (and a fourth for use in foggy weather) are fixed to a frame that can be rotated round a vertical axis at a height of 20 m. on a pole erected near each TL-3 winch. The current is taken from the transportable electric station (40–60 KW.) supplying power to the winches. When skidding is done with tractors the low-power station supplying energy to power saws cannot serve as an efficient source of lighting current. The places where tree-length logs are bundled can be illuminated by the rear lamps of the tractor (for this purpose, a second lamp, rotatable like the standard lamp, is attached to the rear of the tractor cabin). In addition, the working position of each choker-operator should be illuminated by two 500-watt lamps suspended at a height of 8–10 m. Working positions in the forest depot are illuminated with 200- to 500-watt lamps suspended also at 8–10 m. height. [(Forestry Abstracts, V. 14, No. 3]

Rodionov, V. I. Morskie samozatjagivajusciesja ploty. [Sea-going, self-tightening rafts.] *Lesn. Prom.* 12 (3), 1952 (10–2). [Russ.]

An illustrated description of new sea-going rafts suggested in 1950 by Samburskiĭ, and characterized by a self-tightening mechanism by means of a towline passing through a pulley system fixed along the raft. The raft (ca. 90 m. long) consists mainly of 6·5-m. logs arranged in staggered layers. The permanent transverse binding consists of 28 basic and 25 additional chains, while longitudinal stiffening is effected by one bottom (keel) and two upper (deck) cables. On the two latter are fixed staggered pulleys, through all of which a tow-line passes. At each end of the raft it also passes through a locking clamp; if one of

these is released and tractive force applied to the line, the whole system is re-locked. Two experimental rafts of this design were floated on the Caspian from Astrakhan to Baku, and proved superior in all respects to rafts of orthodox design; in particular 25% less gear was required and the 'technical' [average?] speed was 20–30% greater. [Forestry Abstracts, V. 14, No. 3]

Tuovinen, A. Uppoaminen uiton alkuvaiheessa. [Sinking in the initial phase of floating.] *Tied., Metsätebo, Helsinki* No. 74, [1952?] pp. 17. [Fi.e.]

Floating experiments were made on 200 unbarked Pine logs of unbarked 4-m. Pine pulpwood, 200 logs of unbarked 4-m. Spruce pulpwood, 200 partly barked 6-ft. Pine pitprops after storage in the forest, 75 2-m. logs of strip-barked Birch and 75 of Aspen both after storage in the forest. Results, shown in graphs and tables with English legends, include the following: (1) There were no sinkers among the unbarked Pine logs but at the 3rd measurement (24 days after floating began) those waterlogged and of poor buoyancy totalled 2·6%, mostly among logs with little heartwood. The rate of sinking (reduction in floating height as a % of diameter) decreased during the floating period in logs with little heartwood, and increased with logs of high heartwood %. (2) Results of floating unbarked Pine pulpwood were poor. Sinkers were more numerous in small- than in large-diameter classes. Logs containing less than 20% heartwood should have a minimum diameter of 17–18 cm.; with 10–30%, 16 cm; with 30–40%, 15–16 cm.; and with over 40% heartwood, logs with top end diameter of 10 cm. can be economically floated at least for a time. (3) Spruce pulpwood contained much more heartwood than Pine. Despite their lower density, the floating height of Spruce logs was little better than that of Pine of the same diameter and heartwood classes. (4) Pine pit-props floated excellently after piling, in spite of small diameters and low heartwood %. (5) The Birch logs, which were also of small diameter, lost floating height rapidly during the period, the number of sinkers increasing with floating time. (6) Among the Aspen logs, which were of larger diameter, there were no sinkers and floating height remained good. [Forestry Abstracts, V. 14, No. 3]

Wood and Its Properties

Rault, J. P., and Marsh, E. K. The incidence and sylvicultural implications of spiral grain in Pinus Longifolia Rob. in South Africa and its effect on converted timber. Forest Products Institute, Pretoria. 1952. pp. 21. 6 refs. [Commonwealth Forestry Conference, Canada, 1952.]

The recognition of spiral grain, variations in spirality at various levels in the tree, and the utilization of spiral-grained timber are considered. It is pointed out that the most significant factor in limiting the utilization of spiral-grained timber is the amount which a board twists in drying. This was found to be governed by the diameter of the log and the degree of angular spirality in it. The maximum amount of twist in seasoning permissible in boards used for box shooks is considered to be 12° per 10 ft. length, and in those used for structural timber 10° per 10 ft. length. The angular spirality at various diameters at which these maxima are reached is determined by graphical means and presented in tabular form.

The incidence of spirality in stands of *P. longifolia* in So. Africa was determined from observations taken in 300 sample plots, and is presented in tabular form. The data give evidence that genetic factors, age, site quality and rate of growth have effect on spirality but that effects of soil type, climate, and aspect are not significant. Stems of 22 trees were analysed and the relation between the mean length of a completed turn of a spiral, its mid-diameter and angular spirality is examined and leads to the conclusion that, in trees of given age and inherent potential spirality, angular spirality is directly proportional to mean annual increment in d.b.h. Trees of low potential spirality increase slowly in angular spirality up to the age of 10 years, more rapidly between 10 and 20 years, and reach a maximum at 30 years, which is maintained until the age of 60 years when a gradual decrease begins to take effect. Trees of medium potential spirality increase in angular spirality slightly more rapidly than those of the previous type up to the age of 10 years, decidedly more rapidly between 10 and 20 years, at which stage they reach a higher maximum which is maintained until 50 years, whereafter there is a gradual decrease. Trees of high potential spirality increase very rapidly in angular spirality to a still higher maximum, which is reached at 10 years, maintained up to 30 years, and thereafter falls off more rapidly than in the previous types. In trees of normal growth pattern, in which mean annual increment in d.b.h. accelerates up to the age of 20 years and falls off thereafter, both increase and decrease in angular spirality are accelerated and the turning point occurs at earlier ages.

It is concluded that spirality may be controlled either by restriction of diameter increment or by establishing sources from which seed of low potential spirality may be collected. The second alternative is preferred and a means of establishing such sources is suggested. *From authors' summary.* [For. Prod. Util. Abs., V. 13, No. 5]

The timber trade: a Financial Times survey. *Financial Times, London* 19 Jan., 1953. pp. 28.

Contains 20 papers by different authors on supply, markets and distribution; the use of timber in industry, mining, and for flooring; sawmilling; preservation; the plywood, fibre- and building-board, joinery and furniture industries; research and development; and the Timber Trade Federation and Forestry Commission. [Forestry Abstracts, V. 14, No. 3]

Woods, R. P. (World review of the newer timbers and their commercial uses. In Timber Progress and Desk Book for 1953, Cleaver-Hume Press, London. 1952. pp. 31–46.

Lists some of the timbers recently imported from Africa, S. America, and S.E. Asia, and gives a table showing common and scientific names, weight/cu. ft., origin, and actual and possible uses of some 40 species. [Forestry Abstracts, V. 14, No. 3]

Jane, F. W. The structure of new timbers. In Timber Progress and Desk Book for 1953, Cleaver–Hume Press, London. 1952. pp. 20–30.

Discusses the properties of a number of timbers, both softwood and hardwood, that have become available in some quantity since the war, and gives photomicrographs of *Araucaria angustifolia, Anisoptera* sp., *Lophira alata* var. *procera, Phoebe porosa, Daniella fosteri, Koompassia malaccensis* and *Afrormosia elata.* [Forestry Abstracts, V. 14, No. 3]

Mello, E. Cunha. Parque Nacional do Itatiaia. Estudo dendrologico de essencias florestais do Parque Nacional de Itatiaia e os caracteres anatomicos de seus lenhos. [Itatiaia National Park. A dendrological study of forest species of Itatiaia National Park [Brazil], and the anatomical characteristics of the woods.]

Boletim, Serviço Florestal, Ministerio da Agricultura, Rio de Janeiro No. 2, 1950. pp. 174. 46 refs. [Port. port. f.e.g.] X.

Anatomical studies of 30 hardwood species, with descriptions of the trees. [Forestry Abstracts, V. 14, No. 3]

Greenidge, K. N. H. An approach to the study of vessel length in hardwood species. *Amer. J. Bot.* 39 (8), 1952 (570–4). 22 refs. O.B.D.

A survey of total vessel length in 8 diffuse-porous and 3 ring-porous species has revealed marked differences in the length of the conducting elements of these two structural types. In the more highly specialized forms, a single vessel may extend from the secondary wood of the terminals of the upper crown to ground level and possibly into the root system. In diffuse-porous species, however, the water-conducting elements are of determinate length, and in healthy, vigorous, forest-grown material, total vessel length varies between fairly well defined limits. The results of several independent lines of investigation suggest that the vertical rates of water conduction in large woody stems may be closely correlated with total vessel length. In ring-porous woods, moisture moves upwards in channels unobstructed by cross-walls or septa. In less highly specialized

Dielectric properties of wood. *Rep. For. Prod. Res. Bd., Lond. 1950,* 1951 (14–5).

Measurements have been made of the dielectric constant and power factor for the three principal directions of the grain on discs of 12 species, conditioned to relative humidities (r.h.) of 30, 60 and 90%. Both dielectric constant and power factor are greater, in some species considerably so, in the longitudinal than in the transverse directions, and are usually slightly greater for the radial than for the tangential direction. The dielectric constant in all three directions falls with increasing frequency over the range examined (2 kilocycles/sec. to 40 megacycles/sec.). The curve of power factor against frequency, however, shows a minimum at a frequency which rises as the moisture content increases. At a given frequency and moisture content the dielectric constant is proportional to density for all three grain directions; this is as yet unexplained. There is little or no correlation between density and power factor, and when power factor is plotted against moisture content the curve is divided into three distinct regions, the power factor increasing from 0–8% moisture content, remaining steady or decreasing between 8 and 14%, and increasing above 14%. The conductivity of the wood is proportional to the product of frequency, dielectric constant, and power factor; and the irregular behaviour of the power factor is reflected in similar, though less marked, irregularities in the conductivity. In all three directions, at the lower humidities, the logarithm of the conductivity is proportional to the logarithm of the frequency over a certain frequency range which becomes smaller as the moisture content increases (50 kilocycles/sec. to 40 megacycles/sec. for specimens conditioned to 30% r.h., and 500 kilocycles/sec. to 40 megacycles/sec. for specimens conditioned to 60% r.h.). On specimens conditioned to 90% r.h. the change of conductivity with frequency is much less. [For. Prod. Util. Abs., V. 13, No. 5]

Chipboard

Kollmann, F. Herstellung halbschwerer Holzspanplatten im Trockenverfahren. [Manufacture of medium-weight chipboards by a dry method.] *Holz Roh- u. Werkstoff* 10 (4), 1952 (121–34). 16 refs. [G.g.] P.R.

A comprehensive, illustrated account of modern methods of manufacturing medium-weight chipboards (sp. gr. 0.400–0.850), especially boards of sp. gr. 0.500–0.700, without cooking. Medium-weight chipboards, made in large sizes have a planar quasi-isotropy owing to the chaotic arrangement of the 'chips'. Their properties depend upon (1) proportion and kind of binder, (2) pressure applied, and (3) form and size of 'chips'. Long, flat 'chips' give a higher bending strength than short, cylindrical ones. Wide, smooth 'chips' give a smooth surface, while narrow curled ones are easily felted. Large 'chips' cause the formation of loosely-knit spots. Sawdust yields boards with small mechanical strength, even when the binder proportion is relatively high. Fine wood-flour cannot be used for the manufacture of chipboards. The best results are obtained with shavings from planing and peeling, and from comminuted veneer waste. Various machines for (1) peeling to obtain wide and smooth shavings, (2) preliminary comminution, (3) comminution with centrifugal mills (disintegrators) and by chip-cutting, are described and illustrated. Machines for the drying of 'chips' and for mixing them with binders and final processing machines are also described. The usual binders (proportion not over 10%) are synthetic resins of the phenol and urea type. The working pressure for the medium-weight chipboards varies between 7 and 25 kg./sq. cm. [For. Prod. Util. Abs., V. 13, No. 5]

Voss, K. Die Warmebehandlung von Holzfaser–Hartplatten. [Heat treatment of hardboards.] *Holz Roh- u. Werkstoff* 10 (8), 1952 (299–305). 14 refs. [G.g.] P.R.

Presents the results of tests on the properties and behaviour of German resin-bonded hardboards made from softwood waste when subjected to heat treatment of the order 140–180° C./15 min.–50 hr. Water sorption (after 2, and after 24 hr.), and swelling in water have shown similar trends in relation to the duration of heat treatment and the % decrease of water sorption (or swelling) compared with untreated hardboards. The respective sets of curves during the first 5 hr. or so show a rapid fall but thereafter nearly constant values; the higher the temperature of heat treatment the better the quality of hardboard obtained after the same period. Bending and tensile strength tests have shown similar behaviour: heat treatment causes first a slight increase of strength, which, as the period of treatment lengthens, tends to a maximum value (averaging ca. 10% higher than for untreated specimens) after which the strength value drops, rapidly for higher temperatures, less rapidly for lower temperatures. Thus bending strength was increased by 20% after 1 hour, and fell to 50% below normal after 13 hr. treatment at 180°; for 160°, the figures were: + 16% after 2–3 hr., and — 28% after 30 hr.; for 150°, + 12% after 4 hr., and — 18% after 50 hr.; and for 140°, + 12% after 12 hr., and + 4% after 50 hr. Tests on hardboards without a resin binder, made by alkaline process, have shown that heat treatment decreases their water sorption and swelling, and increases their bending strength. [Forestry Abstracts, V. 14, No. 3]

Seasoning

Campbell, G. S. Sub-project S.6–5—Drying schedules for Mountain Ash *(E. regnans)*. Progress report No. 7. Experiment S. 6–5/12—A comparison of the effect of three-shift and one-shift kiln operation on the drying time of 1-in. mixed sawn Mountain Ash *(E. regnans)*. (First report.) Division of Forest Products, C.S.I.R.O., Melbourne. 1952. pp. 9 + 1 gph. P.R.

In drying to a final moisture content of 12% one-shift (i.e. discontinuous) operation seems to require

nearly twice the drying time required for three-shift (continuous) operation. The total time during which heat is supplied to the kiln is much less for one-shift operation than for three-shift operation. *From author's summary.* [Forestry Abstracts, V. 14, No. 3]

Netusil, A. V., and Goljdblatt, B. A. Vysokocastotnaja suska i propitka drevesiny. [High-frenquency drying and impregnation of timber.] *Elektricestvo, Moskva* 1948 (4), (12-7). 18 refs. [Russ.russ.] X.

Discusses the advisability of timber seasoning with R.F. currents. According to one of the papers quoted, over 3 KWH was required to remove 1 kg. of moisture from timber when a frequency of 5–60 megacycles/sec. was used, but only 1.5 KWH/kg. with a frequency of 250–500 kilocycles/sec. There are several dozen medium-wave R.F. seasoning plants operating in Russia, which handle timber up to 11 m. long and 0.3 m. square. Empirical relationships and formulae are presented for calculating the losses of electrical energy in seasoned timber, taking the anisotropy of wood structure into consideration. A 50-KW R.F. generator for timber seasoning is described. Two types of metal-gauze electrodes are used: horizontal and vertical. Irregular seasoning due to non-uniform heating is avoided by an intermittent seasoning schedule in which heating to ca. 100° C. is followed by slow cooling, then subsequent heatings and coolings. The impregnation of timber so seasoned is effected by simply dipping the hot timber into the preservative; the vacuum formed in the interior of the timber by the condensation of water vapour draws the preservative into the pores. [For. Prod. Util. Abs., V. 13, No. 5]

Lindenthal, W. Wood swelling composition and a joint produced therewith. *U. S. Patent No. 2,580,-308, Dec. 25, 1951. pp. 6. P.O.*

A joint of a mortise-and-tenon type, at least one of whose members is of wood, and at least one other is impregnated with a composition consisting of 4–12 parts of natural resin of acidic character, 4–12 parts of an oxygenated solvent of low molecular weight, and 2–8 parts of a basic substance. [Forestry Abstracts, V. 14, No. 3]

Pulp and Paper

Storage conditions for sulfite pulpwood. Christian Kaijser. Svensk Papperstidn. 55, 173–5(1952).

Following a general discussion of storage conditions for pulpwood in the woodyard and under water, results are given from an investigation of moisture content and its distribution in logs stored under different conditions and the effect of resulting uneven moisture distribution on yield of sulfite pulp. J. R. Salvesen [Chem. Abs. V. 46, No. 22.]

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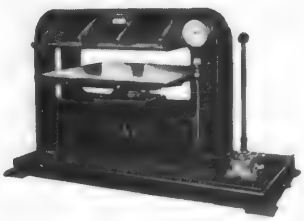
Presses



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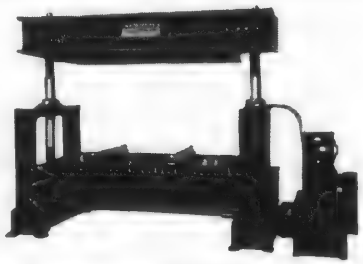

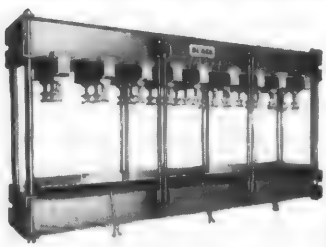

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FPRS NEWS-DIGEST

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Volume 3 SEPTEMBER, 1953 Number 9

Eastern Canadian Section Schedules Fall Evening Meeting

The Eastern Canadian Section will hold an evening dinner meeting October 29, 1953, at Le Cercle Universitaire de Montreal, Montreal, Ont., in conjunction with the Canadian Hardwood and Veneer and Plywood Ass'n. and the Quebec Furniture Manufacturers' Ass'n. Harold Holdsworth, International Fiber Board and Plywood Sales Corp., Gatineau, Ont., will give a talk, illustrated with slides, on birch plywood grades. Representatives of the furniture industry will be asked to comment.

Although the meeting is planned on an area basis, all members are urged to attend.

Ohio Valley Meets October 9 at Cincinnati

The Ohio Valley Section of the Forest Products Research Society will hold its fall meeting October 9, at Cincinnati, Ohio. The Baldwin Piano Co. will be host to the meeting. Those attending will tour the company's plant and see the many complex woodworking operations involved in the manufacture of fine pianos.

The morning technical session, business meeting and luncheon will be held at the Hotel Alms. A luncheon speaker will discuss research and the future of wood.

Further details are available from (Secretary).

Carolinas–Chesapeake to Meet at Richmond October 23–24

The Carolinas–Chesapeake Section will hold a two-day meeting at the Jefferson Hotel, Richmond, Virginia, October 23–24. The meeting will consist of a series of panel discussions covering subjects of regional interest. The program will be released shortly. Several field trips are also being planned in conjunction with the meeting.

Upper Mississippi Valley Meeting at Duluth, October 6

A one-day meeting of the Mississippi Valley Section at Duluth October 6 will feature debarking as the theme, with a demonstration of various types of debarkers at the wood yard of Superior Wood Products as a highlight. It is expected that representatives of three debarker manufacturers will take part in a panel discussion led by Lee Hooker, School of Mining and Technology, Houghton, Mich.

Other papers will include Purchasing Wood By Weight, by Harold Olson, Wood Conversion Co., Cloquet, Minn., and the luncheon address by Fred J. Voss, Vice-president and Chief Engineer of the Duluth, Missabe and Iron Range Railway. Mr. Voss will present the story behind the decision of his company to make a major rail line extension to Forest Center, Minn., to serve forest products industries.

At a Paul Bunyan Smoker the evening of Oct. 5, Dana Worrell of Halverson Trees, Inc., will describe the harvesting and chemical treatment of Christmas trees on a mass production basis.

For further information about this meeting contact William A. Kluender, Section Secretary, Chicago and Northwestern Railway, 275 East Fourth St., St. Paul 1, Minn.

Fall Great Lakes Meeting to Study HF Bonding

Great Lakes Section plans a fall meeting the first week in November at Grand Rapids, Mich. The program will be devoted entirely to high frequency bonding equipment and its use.

Ohio Valley Nominating Committee

Recently announced Nominating Committee for the Ohio Valley Section is as follows: Richard K. Stem, Chester B. Stem Co., New Albany, Ind., Chairman; Hal Moser, Gamble Bros., Inc., Louisville, Ky.; and Ralph K. Day, Central States Experiment Station, Columbus, Ohio.

IMPORTANT FPRS DATES

Oct. 6, 1953: Upper Mississippi Valley Section Meeting at Duluth, Minn.

Oct. 9, 1953: Ohio Valley Section Meeting at Cincinnati, Ohio. (Host plant: Baldwin Piano Co.)

Oct. 13, 1953: Pacific Northwest Section Meeting at Seattle, Wash.

Oct. 23–24, 1953: Carolinas–Chesapeake Section Meeting at Richmond, Va.

Oct. 29, 1953: Eastern Canadian Section Meeting at Montreal, Ont.

Oct. 30–31, 1953: Florida–Georgia–Alabama Section Meeting at Radium Springs, Ga.

Nov. 5–6, 1953: Northeast Section Meeting at New Haven, Conn.

Nov. 9–10, 1953: Deep South Section Meeting at Lufkin, Texas.

Early Nov., 1953: Great Lakes Section Meeting at Grand Rapids, Mich.

Nov. (first week), 1953: Midwest Section Meeting at Chicago, Ill.

March 4–5, 1954: Eastern Canadian Section Meeting at Chateua Laurior, Ottawa.

Knife Nomenclature

At a July 23 meeting of the Knife Nomenclature Subcommittee of the FPRS Machine and Equipment Subject Matter Committee preliminary discussion of nomenclature problems took place, as well as discussion on the first draft of the knife drawings. A revised sketch was drawn up and approved. L. A. Patronsky, Chairman of the Committee, will contact various manufacturers of knives and woodworking equipment to elicit their comments on the drawings. Next meeting of the committee is scheduled for the week of Sept. 14 at the Blackstone hotel, Chicago in connection with the meeting of the Ass'n. of Mfgrs. of Woodworking Machinery. Rex Reynolds, Kennametal Inc., will arrange exact time and meeting place.

INDUSTRY NEWS

North Carolina Forestry Association to Sponsor Equipment Show at Fall Meeting in Lenoir, N. C.

The biggest and best logging and equipment show ever held in the South will be held at the Patterson School for Boys, Lenoir, N. C., on September 23 and 24, according to James T. Broyhill, General Chairman of the meeting. Under the sponsorship of the North Carolina Forestry Association, the show is open to everyone with no charge, for admission.

According to Roy M. Carter and John L. Gray, Show Committeemen, over fifty dealers have already signed for space in the exhibits. Facilities for this show include a large field for outdoor equipment exhibits, a logging area for in-the-woods demonstrations, and a large tent for displays and non-operating equipment which must be set up under shelter. In addition the facilities of the School Gym will be available and meals will be available to those attending through concessionaires. Every type of equipment will be shown, and whether it is run by electricity, gasoline, or other fuel, provisions for running same will be available in the space set aside for the show.

Any company or individual who desires to exhibit equipment is asked to contact the North Carolina Forestry Association, Drawer 2946, Raleigh, N. C., and complete information will be mailed. In sponsoring this Equipment Show in connection with its Fall Meeting at Lenoir, N. C., the North Carolina Forestry Association, under its present president, Roger W. Wolcott, Raleigh, hopes to bring the furniture and wood using industries closer to the wood producing industries. A sufficient supply of raw materials is essential to the future operation of the wood using industries in North Carolina, and good forestry practices by the wood producers, with the proper use of machinery and labor saving devices will assure a future supply of wood.

New Testing Machine Installed at VPI

The latest type universal testing machine with a double torque-bar weighting unit has just been installed in the air-conditioned Wood Research Laboratory of the Virginia Polytechnic Institute. The electrically controlled machine has a capacity of 12,000 pounds and a sensitivity of one-tenth of a pound. It is provided with an automatic electronic recorder to produce stress-strain curves at magnifications from 1:1 to 1000:1.

The machine was made available by the V.P.I. Research Foundation with funds coming from industries that have been served by the Laboratory. It is to be used especially for research on fastening wood, particularly as concerns nails and staples.

Pulpwood Handling

A recent two-day meeting of the Technical Committee of the American Pulpwood Ass'n. held at Old Town, Me., was devoted to field trips to view pulpwood hauling and handling equipment in operation, and to a series of technical papers.

Walton Smith Promoted

Walton R. Smith, has been promoted to Chief of the Forest Utilization Service at the Southeastern Experiment Station, Ashville, N. C.

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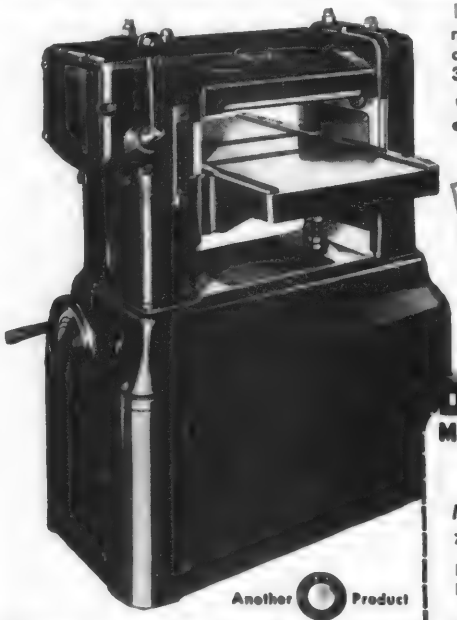

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Except for two years as president of Walton Lumber Co., Smith has been with FUS since its organization in 1944. He has served with the U. S. Forest Service for 18 years throughout the southern states and at the Forest Products Laboratory in Madison, Wis.

Smith's work as Chief of FUS at Ashville involves representing the Forest Products Laboratory in contract with industries from Virginia to Florida.

Hickory Utilization

Committee Chairmen of the newly formed "Hickory Task Force" met at the Southeastern Forest Experiment Station, Asheville, N. C., July 23–24, and made plans for the preparation of more than 20 reports over the next three years on various problems pertaining to the development of new markets for the increasing quantities of medium and low grade hickory found in eastern forests. The meeting was a follow-up of an original meeting in April at which federal, state and industrial representatives launched at 3- to 5-year program to promote the increased utilization of hickory.

Committee Chairmen attending the Asheville meeting were as follows: Executive Committee Chairman, Walton R. Smith, Southeastern Forest Experiment Station, Asheville, N. C.; Growth and Properties, John T. Drow, Forest Products Laboratory, Madison, Wis.; Primary and Secondary Manufacturing and Seasoning; Roy M. Carter, School of Forestry, N. C. State College, Raleigh, N. C.; Products Manufactured from Hickory, W. N. Darwin, Chief, Forest Utilization Section, Tennessee Valley Authority, Norris, Tenn.; Treating and Uses of Treated Hickory, Monie S. Hudson, Research Chemist, Taylor–Colquitt Company, Spartanburg, S. C.; Hickory for Fiber and Fuel, C. E. Libby, Professor of N. C. State College, Raleigh, N. C.; Marketing of Hickory, Richard D. Lane, Central States Forest Experiment Station, Carbondale, Ill. Roger Anderson, Duke University, Chairman of the Committee on Enemies of Hickory, was unable to attend, but was represented by George H. Hepting as Acting Chairman.

Chemical Barking Research

Reporting on results of a two-year old resarch program sponsored by 13 firms in the pulp and paper industry. W. S. Bromley of the Chemical Debarking Research Project, 220 E. 42nd St., New York City, states that results to date indicate that chemicals daubed on trees girdled for pulpwood harvesting is practical and should be beneficial to the industry.

"Chemically-treated trees may be peeled during eight to ten months of the year, whereas sap peeling can be done for only eight to twelve weeks," Bromley explains. Thus steady work throughout most of the year is possible for peeling crews. Other advantages include: cleaner wood than with mechanical debarking; practically no wood waste; use of crooked trees otherwise hard to debark; and opportunity for better forest management practices.

New Designated Representative for Gunnison Homes

With the recent appointment of William J. Messingschlager as assistant to the President of Gunnison Homes, Inc., FPRS Supporting Member, G. O. Johnson, has been appointed to the position of Director of Product Development and Research, and will hence-forth serve as Designated Member to the Society in place of Mr. Messingschlager. Mr. Johnson's headquarters will be the New Product Development Center at Gunnison Homes' new plant, P. O. Box 1107, Harrisburg, Penna.

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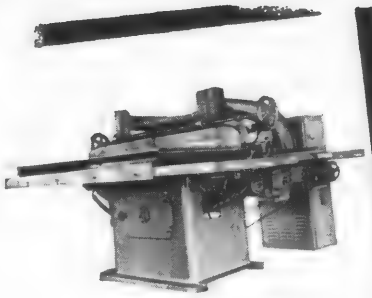

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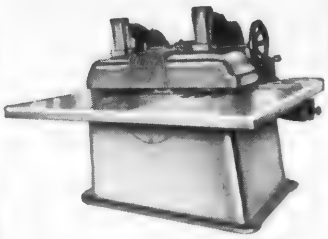
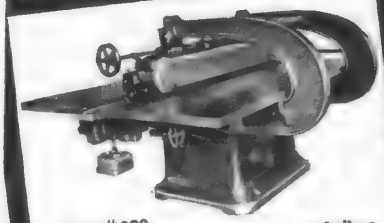
Compare Design

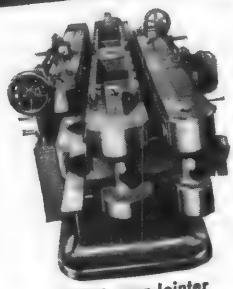
Diehl precision woodworking machines are streamlined for specific *reasons:* More simplified, more "fool-proof" operation—faster set-up with less adjustment—greater safety for your operators.



Diehl #99 Multi-Rip Saw



Diehl #890 Tapeless Veneer Splicer

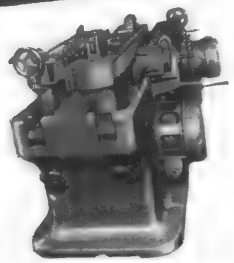


Diehl #69 Veneer Jointer and Edge Gluer

Compare Construction

Massive, rigid construction eliminates vibrations—provides built-in precision. Result is *longer* operating life, *lower* maintenance costs.

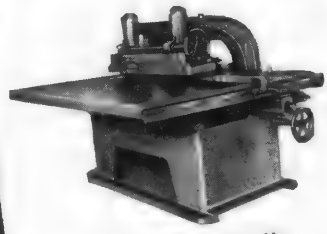
Diehl . . . Standard of Comparison in the Woodworking Industry . . .



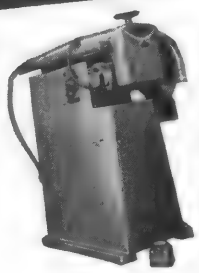
Diehl #660 Glue Jointer and Edge Moulder

Compare Performance

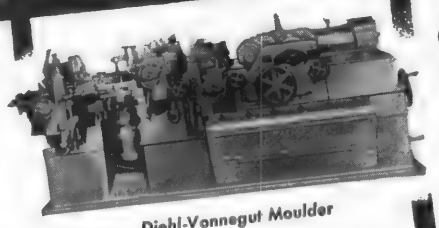
Diehl precision woodworking machines are capable of higher-speed operation with more consistent accuracy—*more wood worked per day with less labor costs.*



Diehl #750 Straight Line Glue Joint Rip Saw



Diehl #725 Straight Line Cut-off Saw



Diehl-Vonnegut Moulder

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today—he'll be glad to show you a Diehl precision woodworking machine at work in a nearby plant.

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Corporate Change

The Colonial Development Corp., a British Government Agency active in developing timber resources in British Guiana, has announced formation of a new company, Greenheart (Demerara) Inc., to take over activities in U. S. previously handled by Greenheart and Wallaba Timber Co., Inc. Address of the new firm is 52 Vanderbilt Ave., New York 17, N. Y.

Forest Industry Teaching Aids

1953–54 Bibliography of Forest Industry Teaching Aids. 12-page booklet lists wide range of up-to-the-minute teaching aids now available from individual pulp and paper companies, lumber manufacturers, plywood and veneer firms, and forestry associations. Special instructions are given for ordering in each case. Available: American Forest Products Industries, Inc., 1816 N. Street, N. W., Washington 6, D. C.

Board Meeting

The FPRS Executive Board will meet Sept. 24–25 at the Brown Palace hotel, Denver, Colorado, to act on current Society matters that require decisions and action.

New Publications

Current reports, books, statistics and other pertinent publications are invited for review in these columns. Address the Editor, FPRS, Box 2010, University Station, Madison 5, Wis. **Please Note:** Your Executive Office has available only one file copy of publications reviewed in these columns. You should request copies of publications direct from sources indicated.

A Small Electrically Heated Dry Kiln. (Technical Note No. 12.) Aimed at helping solve the widespread need for better lumber drying methods for secondary wood processing plants in the Tennessee Valley, description is given of construction and operation of small electrically heated kiln that has been in operation long enough to prove its worth. Data presented on first seven charges indicate the kiln is capable of doing a good job of commercial drying at reasonable cost. Volumes of charges, unit sizes of pieces, beginning and final moisture content, drying time, electric energy, used, and cost of same, are given. Average charge is about 5400. *Available:* Tennessee Valley Authority, Norris, Tenn.

Secondary Logging. Recent study reported in July issue of Oregon Forest Products Laboratory Notes indicate that in Douglas county, Oregon, from two to eight thousand board feet of sawlogs are available on recently cut-over lands. This amounts to from 600 to 1,600 cubic feet, or about 7.5 to 20 cords. Many of areas studied look promising for secondary logging operations. Available: Oregon Forest Products Laboratory, Corvallis, Oregon.

Ad Interim Report on Project 301–B: Preservative Treatment of Electric Fence Stakes. Reports condition of some 1,400 2-inch square stakes treated with 34 formulations of oil-borne wood preservatives. This report, at end of first five years of test, is not final and no conclusions are drawn or implied. *Available:* U. of Illinois, Agricultural Experiment Station, Urbana, Ill.

The following publications are available from the U. S. Forest Products Laboratory, Madison 5, Wis.

The Detection and Relief of Case-Hardening. (Tech. Note No. 213.) Case-hardening results when the surface of lumber becomes dry but cannot shrink fully because center does not shrink until later. Surface layers therefore become set in an expanded condition and when center of lumber does become dry and tries to shrink fully, stresses are set up. Method for testing for moisture content and case-hardening are explained.

Diffusion and Penetration Mechanism of Liquids into Wood. A. J. Stamm. (Reprinted from Pulp and Paper Magazine of Canada) Present knowledge of passage of gases, vapours, liquids, and dissolved materials through wood is reviewed by considering the movement of each under different motivating forces. Specifically, previous and new data on the mechanism of penetration of pulping liquors into chips or blocks with chip lengths are considered. New data shows that the rate of natural penetration of water into wood in the fiber direction at different temperatures varies as the vapour pressure and the inward diffusion of the vapour.

Survey of Strength and Related Properties of Yellow-Poplar. R. F. Luxford and L. W. Wood. (Report No. 1516, revised) Tests reported were made on specimens from 96 boards obtained from seven mills in the southern Appalachian district. Eleven stain and color groups of sapwood and heartwood were recognized in stock used. Tests reported include static bending, toughness, compression parallel to the grain, compression perpendicular to the grain, hardness, shear parallel to the grain, cleavage, and tension perpendicular to the grain.

Plastic or Mastic Coverings for Exterior Walls of Houses. F. L. Browne, U.S.F.P.L. Report No. R1937. Analyzes plastic coverings being promoted by applicators. Suggests possible shortcomings and cautions against taking claims at face value. and faults such coverings are supposed to cure probably result from conditions in other fields than paints. Many claims are not readily provable

Computed Thermal Conductivity of Common Woods. (Tech. Note No. 248.) Formulas for expressing conductivity, specific gravity, moisture content relationship are given. Chart—with explanation of use—is given to find thermal conductivity of various common woods.

Methods of Controlling Humidity in Woodworking Plants. (USFPL Report No. R1612) Reviews need for control of humidity control and describes methods of control including air conditioning, heating, humidification and dehumidification.

List of Publications on Pulp and Paper. (USFPL Report No. R444) Lists publications and reprints of articles under wide variety of specific headings that are currently available. Tells where various papers can be obtained.

List of Publications on The Growth, Structure, and Identification of Wood. (USFPL Report No. R177) Lists publications and reprints of articles available on subject. Tells where various papers can be obtained.

Protecting Green Lumber from Decay During Shipment. (Forest Pathology Special Release No. 26) Lists various chemicals that are effective in preventing decay in green lumber during shipment. Points out that infections that have started during shipment, but have not yet done real damage, too often continue to develop in later service before wood has a chance to dry.

Use of Engelmann Spruce for House Construction. (Report No. R1944–1) Describes various places where Engelmann Spruce may be used satisfactorily, pointing out that major uses will probably be for studding, sheathing, subflooring and so forth.

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SAW MILL WASTE

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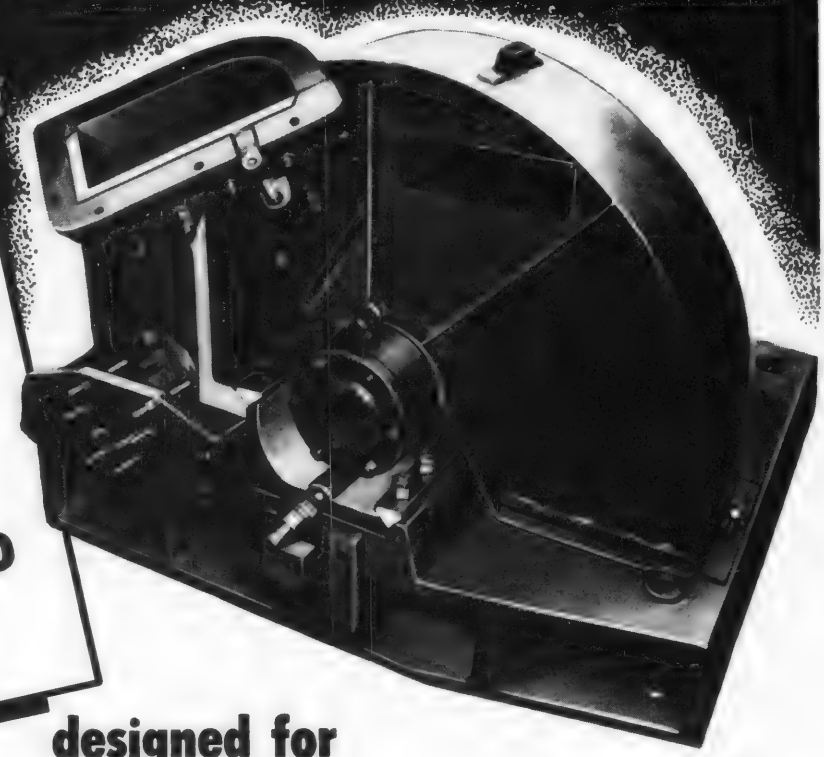
VENEER CORES!



New MURCO HIGH-SPEED MULTI-KNIFE WASTEWOOD CHIPPER

designed for heavy duty service

Into MURCO wastewood chippers go the experience of more than 30 years of designing and manufacturing chippers that have proven successful all over the United States and many foreign countries . . . today D. J. Murray Manufacturing Company is considered a leader of chipper developments and modern design.

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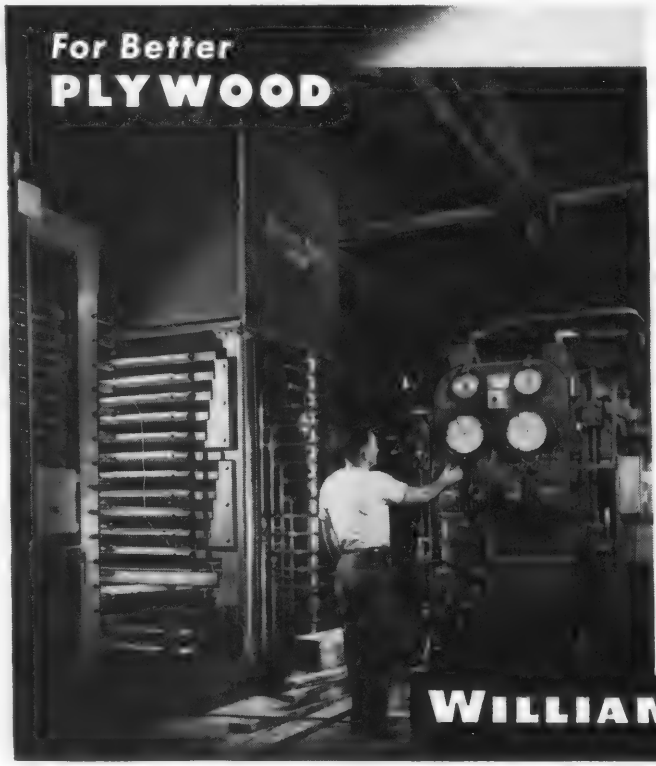

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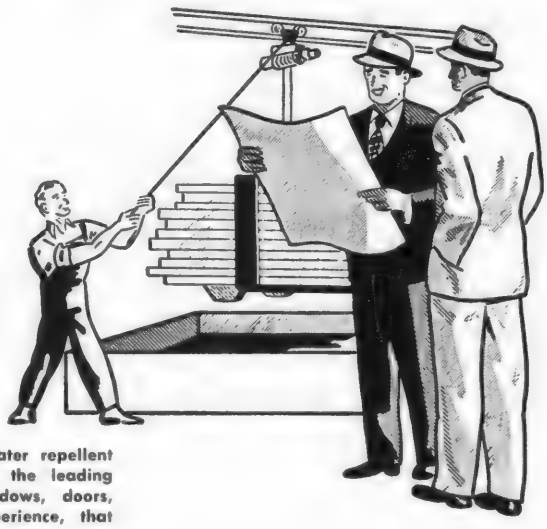

first choice . . . of men who know wood preservation

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Also . . . among the men who KNOW, "Protection Products" is chosen for its engineering "know-how" in treating processes—including DRI-VAC, the modern vacuum method developed in their laboratories and now attracting such wide spread interest.

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do you know all potentialities of wood residues?

CHEMICAL PROCESSING OF WOOD

By ALFRED J. STAMM, Ph. D.
Chief, Division of Derived Products

and ELWIN E. HARRIS, Ph. D.
Subject Matter Specialist in Wood Hydrolysis and Lignin Chemistry
Forest Products Laboratory, U. S. Department of Agriculture,
Madison, Wisconsin

contains all the answers.

A unique compilation of scattered data

This book was written with the object of assembling all available information on the chemical utilization of wood, especially of wood residues and inferior species of wood, by both conventional and new methods, to produce modified wood products, pulp products and various derived chemicals.

The chief emphasis is placed on the more recently developed processes which have not been previously included in books. To make this material readily understandable and usable, introductory chapters have been devoted to the fundamental physical and chemical properties of wood.

CONTENTS

CHAPTER

1. Wood as a Chemical Raw Material.
2. The Constituents of Wood.
3. Structure of Wood.
4. Surface Properties of Wood.
5. Mechanical and Thermal Properties of Wood and Wood Products.
6. Drying Wood.
7. Preservative and Fire-retardant Treatments of Wood.
8. Modified Woods.
9. Wood-base Plastics.
10. Pulp and Paper.
11. Pulp Boards and Paper-base Laminates.
12. Cellulose Derivatives.
13. Tree Exudates.
14. Destructive Distillation of Wood.
15. Extractives.
16. Wood Hydrolysis.
17. Hydrogenation of Wood and Wood Products.
18. Miscellaneous Products from Wood.

New techniques

The manufacture of Impreg and Compreg, the preparation of Staypak and acetylated wood, new techniques for molding these and other products, wood-base plastics, high-strength paper laminates, lignin-filled laminates, pulp preforms, low-density core materials, chemical seasoning and solvent seasoning methods, hydrogenation of lignin and wood, wood-sugar molasses, fermentation products, growing yeast and wood sugars, and vanillin production from wood are among the many interesting topics covered in this comprehensive volume.

A critical review of all wood modifying processes

The book is not a mere compilation of literature data, but a critical survey which presents both the favorable and unfavorable features of each process, together with the economic limitations.

Although it was written primarily for the chemist and engineer, the simple and straightforward style will make this book profitable reading to businessmen and executives who are interested in the utilization of our natural resources. It is also suitable as a text, especially for forestry schools.

Interesting illustrations and an extensive bibliography at the end of each chapter round out the value of this book.

595 pages • illustrated • $12.00

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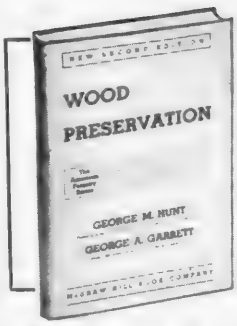

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WOOD PRESERVATION

Second Edition

By George M. Hunt and George A. Garratt

Here is a completely up-to-date guide book for all interested in the materials and methods of prolonging the life of wood or improving its usefulness by treatment with chemicals or by sanitary precautions.

Hunt and Garratt cover the entire field of wood preservation, including the natural durability and treatability of different woods . . . descriptions of the important fungi and insects that damage wood in storage and in use . . . and descriptions of the more common wood preservatives along with methods of evaluating such preservatives.

Plus this, you see how to protect logs and lumber from deterioration during seasoning and storage . . . how to prepare timber for treatment . . . how to treat wood with preservatives . . . what the effect of treatment on wood properties is. You get a close examination of equipment and operation methods of treating plants . . . fireproofing chemicals and methods . . . and the economic aspects of wood preservation. **By George M. Hunt, Former Director, U. S. Forest Products Laboratory, and George A. Garratt, Dean, Yale School of Forestry, 2nd Ed., 445 pages, 112 illus., $7.50 to FPRS members $6.75**

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Five years ago, Orsenigo found it could speed production and maintain quality by using National's WOOD-LOK glue for assembly work. WOOD-LOK is ready for use. No time lost in preparing glue. No chance for error in mixing. And it has a storage and working life of many months.

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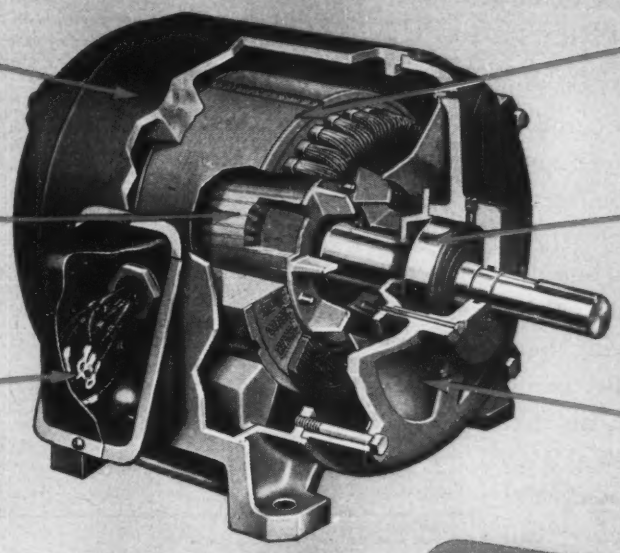

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BELCOBALSA CORE STOCK COMES CUT-TO-SIZE, READY TO GLUE

Because it is delivered ready for gluing or dry assembly, Belcobalsa Certified Kilndried Core Stock saves time, labor and lumber. Belcobalsa comes dressed, trimmed and ripped exactly to specifications, and bundled according to size. Thus, Belcobalsa eliminates costly processing, handling and sorting. And the manufacturer avoids lumber waste that might otherwise run as high as 35% of total core stock purchased. *Yet Belcobalsa is priced no higher than core stock delivered in random lengths and widths. In other words, Belcobalsa reaches the assembly line at lower cost.*

REDUCES COST OF SHIPPING YOUR FINISHED PRODUCTS

Belcobalsa is the lightest in weight of commercial woods. Two men can easily unload a carload of Belcobalsa Core Stock. Users of Belcobalsa enjoy resultant savings not only in initial handling, but in handling and shipping of finished products. One manufacturer, for example, has reported saving $600 in freight charges per carload of finished goods!

COMPARE THE YIELD OF BELCOBALSA WITH YOUR PRESENT CORE STOCK

Here is a sample yield comparison of Belcobalsa with the typical core stock now in common use for the manufacture of flush doors. Whatever your product may be, our engineers will be happy to help you make a similar comparison with any other core stock you use, or are considering!

	Standard Softwood or Hardwood Core Stock	BELCOBALSA
Grade delivered	No. 2 B Common or equivalent	Select, free of major defects
Dryness	Green	Certified KILN DRIED
Finish	Rough	Fine saw finish or S1S
Thickness purchased	8/4"	7/4"
Lengths	Random	Cut-to-length
Widths	Random	Cut-to-fixed widths
WORK EFFECTED AT DOOR PLANT		
Kiln drying with corresponding shrinkage	yes	NO
Cutting off defects	yes	NO
Ripping into core strips	yes	NO
Trimming to length	yes	NO
Estimated yield of core stock	65%	100%
Equivalent footage on 4/4" basis including labor cost figured in boardfeet	1,800 boardfeet	1,000 boardfeet
Lumber needed per 1,000 square feet of core		
Hardwood or Softwood, 8/4" requir.	3,600 boardfeet	
BELCOBALSA 7/4" requir.		1,750 boardfeet
Assuming that a solid core door 1¾" x 3-0 x 6-8 has 16 sq. ft. of core: 1,000 boardfeet of hardwood or softwood will make	17 Doors	
1,000 boardfeet of BELCOBALSA will make		36 Doors

CERTIFIED KILNDRIED

Every boardfoot of Belcobalsa is dried in our own kilns. Our Ecuador plant now has 12 Moore Dry Kilns with a capacity of 2,000,000 boardfeet. This means another major saving in your processing cost — and it means there is no shrinkage loss after Belcobalsa is delivered to you.

Remember: Belcobalsa Certified Kilndried Core Stock reduces the weight of your panels because of its low, uniform density; makes them warp-resistant because of its inherent stability.

BELCOBALSA CORE STOCK ELIMINATES THESE FIVE OPERATIONS:

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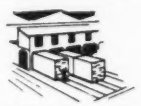

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REGISTERED TRADE MARK

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BALSA ECUADOR LUMBER CORPORATION

500 Fifth Avenue, New York 36, N. Y. Pennsylvania 6-0697

MATTISON 276 MOULDER

- **REDUCED COST ON FITTING AND SANDING OPERATION**
- **SUBSTANTIALLY IMPROVED QUALITY OF MOULDING WORK**

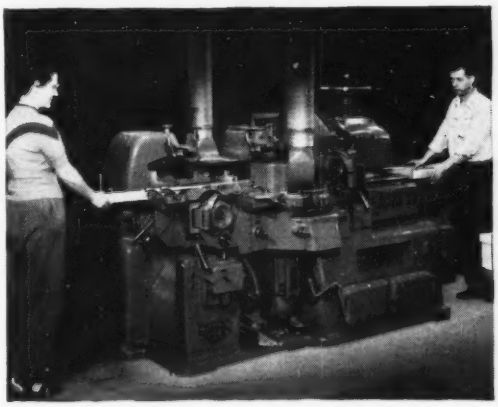
FOR

IMPERIAL FURNITURE COMPANY

Operator

FINDS MATTISON 276 . . .

- **Easy to set up**
- **Stays put**
- **Vertical and cross adjustment of Cutterheads are made quickly and positively**
- **Outboard bearings eliminate vibration in heavy cuts**
- **Attached wrenches simplify setting of guides**



IMPERIAL FURNITURE COMPANY
Imperial Tables
GRAND RAPIDS-2-MICHIGAN

March 18, 1953

Mattison Machine Works
Rockford, Illinois

Gentlemen:

Early this year, we installed one of your No. 276 Heavy-Duty High Speed Electric Moulders. We thought you might like to know how we are getting along with this machine.

Here at Imperial, we manufacture a complete line of high grade tables, and the moulder work must be as nearly perfect as possible to reduce our sanding and fitting operations. With the addition of this Mattison No. 276, the quality of our moulded work has improved substantially while our costs have gone down.

Our operators find this Mattison No. 276 very easy to set up, due to the accessibility of all the adjustments and controls. Vertical and cross adjustments of the cutterheads are made positively and quickly, and the hand locking wrenches which are attached to the machine simplify setting of the guides. Another feature is that it "stays put", which is no doubt due to the rigid construction, precision manufacture, and advanced engineering design. The outboard bearings eliminate vibration in heavy cuts, and we believe that any high speed moulder spindle should have an outboard bearing.

We are confident that this machine will continue to perform efficiently for a great many years.

Yours very truly,

IMPERIAL FURNITURE COMPANY

A. F. Christy

A. F. Christy
Plant Manager

- Imperial Furniture Company's reputation for building a high quality line of tables is in a good measure due to precise fabrication methods which insures consistently accurate results and proper fitting of all parts. Mr. A. F. Christy, Plant Manager of Imperial, has been around the woodworking industry for a good many years and knows what he wants and has to have in the way of production and accurate results. The above letter telling of his experience with the Mattison 276 Moulder is an example of what this machine is doing for a good many others. For complete information on the Mattison 276 High Speed Electric Moulder, ask us to send you our latest free circular.

MATTISON MACHINE WORKS

ROCKFORD · ILLINOIS

HYDRAULIC PRESSES

Your Problem is our Problem

FIRST IN DESIGN!
FIRST IN QUALITY!
FIRST IN EXPERIENCE!

HOW CAN WE HELP YOU?

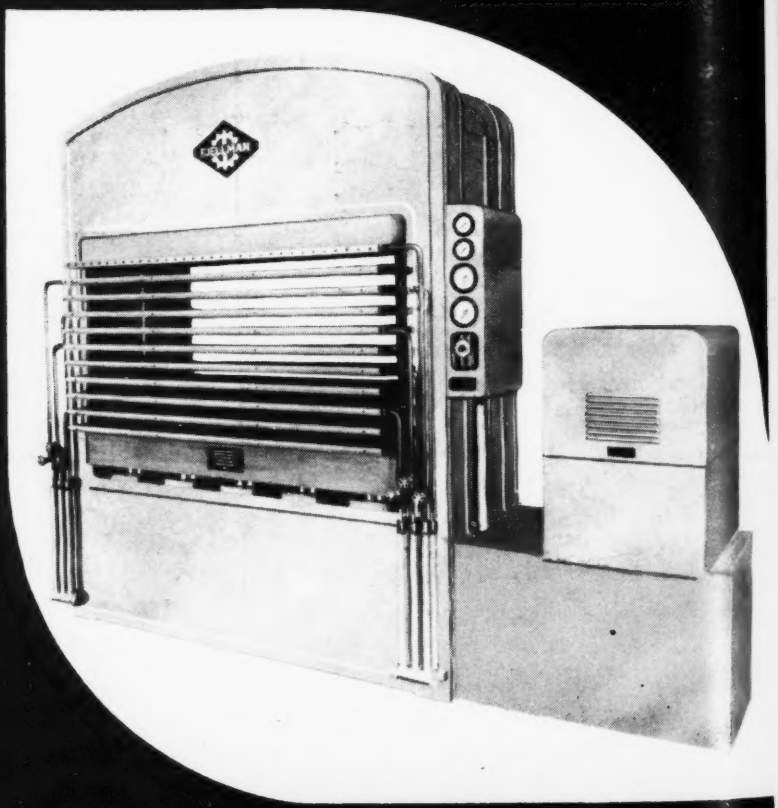
What is the record of the Fjellman & Winther Company during the last year?

For one thing . . . 15 press units were installed by F.W. engineers within the last fiscal year . . . with all parties concerned completely satisfied!

When customers will take the trouble to write complimentary letters . . . that's the time a company can feel reasonably sure it is on its way to the top.

Satisfied customers is the reason for Fjellman & Winther Company's growing popularity . . . and why more and more manufacturers of laminates are turning to F.W. engineers with confidence and repeat orders.

The name Fjellman is recogized as being FIRST in design . . . FIRST in QUALITY . . . FIRST in EXPERIENCE!



Write for engineering data and our financing plan.
Write for our general catalog.

FJELLMAN & WINTHER

P. O. Box 1205 Telephone Joliet 9209